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Innovation in the European Food Products and Beverages Industry

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INDUSTRY STUDIES OF INNOVATION USING CIS DATA

Study on Innovation in the European Food Products and Beverages Industry

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For

The European Commission

by

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1.1 The importance of the industry

Both in terms of employment and production the food and beverages industry is one of the world's largest businesses. Annual global sales of packaged food reached US$ 2.8 trillion in the early 1990s and the market for processed food has grown particularly quickly. Profitability has consistently been high, even in recession years, and the vigour of the industry thus performs an important countercyclical function. The present Report investigates the conditions for the industry to perform successfully.

1.2 Innovations and supply in the industry

1.2.1 A "low-tech" industry?

The food and beverages industry has generally been regarded as a "low-tech" industry. In the present Report we do not claim that the industry in isolation is very technologically advanced (although some of the firms within the industry indeed are). But we do argue that the traditional perception of the industry does not render full justice to the innovativeness of food and beverages firms in general. In fact, we find that a substantial level of innovation activity of diversified kinds is taking place. The considerable size of this industry in many economies implies that many of its firms will be especially responsible for making use of innovations developed in other technologically more advanced industries (e.g. biotechnology). Secondly, we claim that it is already near the forefront of industries in the *application* of a breadth of different scientific advances, i.e. innovating by means of "new combinations" of scientific disciplines. Thirdly, and partly as a result, we also claim that the industry possesses high potential for future economic growth, by dint of becoming a "carrier industry" for embodying technological advances developed upstream.

1.2.2 A "supplier-dominated" industry?

Despite its "low-tech" reputation, a striking observation from the study is the radical nature of both product and process innovation in the industry over the past twenty years or so. While this has frequently been pointed out in regard to the "high-tech" industries, it has much less often been noted as pervading a range of industries usually regarded as being rather "low-tech", like food-processing. Of course there is a high degree of dependence on those developments in high-tech areas, like information technology, biotechnology and advanced materials; but there is much more to pervasiveness than the simple “supplier-dominated” view of such industries would suggest. In particular, we can draw attention to the great variety of technological impulses - the range of scientific disciplines and technological fields - which suppliers are being called on to deliver to these “users”, and still more to the complexity of integrating all of these through indigenous efforts within the user industry such as food processing.

1.3 The role of demand in innovation

1.3.1 Demand and technological development

The supply-side factors are one reason why we find that the “supplier-dominated” label is no longer adequate as a characterisation of this industry. But the most important reasons lie on the demand side. For one thing, firms in this industry assess product innovations as being as important as process innovations in their goals of innovation, and see market developments as more important than either. A second argument in this connection is that clients or customers, not suppliers, emerge as the most important single source of information for innovation. Suppliers of materials and components and suppliers of equipment are listed as second and third respectively. Except for “conferences, meetings, and journals”, the technology factors appraised here have had negligible importance as a source of information to the innovation process alongside market factors. We also find indications of the considerable importance of proximity between users and producers.

1.3.2 The role of final demand

Changes on the demand side are being exerted not only through intermediate demand, e.g. of manufacturers for technologies, but also through final demand: through consumer behaviour (including the effects of “globalization” of tastes and products), through public opinion, and through intensifying regulatory standards (in regard to health, safety, environment, etc.), which are of course partly by way of response to public opinion. The shift of emphasis from technology to product is altering the nature of process change in the sense of how automation is developing, and also altering the divisional structure of large firms and the nature of competition and collaboration in the industry. The interactions between the supply-side elements (different technologies etc.), and especially between the demand side and the supply side, are likely to prove the key determinants of national and supranational success in innovation in the industry. In our specific research - using the CIS data provided, but including other data sources as well - we find a remarkable emphasis on creating new markets when firms list their objectives for innovation.

1.4 The role of demand in consumption patterns

1.4.1 The national systems of consumption

Demand patterns show evidence of "globalization", resulting from such factors as: better means of transportation and communication; increased tourism; the forging of the European single market; and the internationalization of firms within the industry. Despite these trends towards internationalization of consumer tastes, we find that Europe is still by no means homogeneous with respect to food and drink culture. Far from it: there are large differences both in the actual content of the culture and in the degree of homogeneity of the nations. Furthermore, national borders are of great importance in distinguishing these different cultures. A large degree of overlap between linguistic regions and food culture regions suggests that the consumption patterns are deeply rooted in the historical and cultural development of the nations.

1.4.2 National tastes and external competitiveness

The results clearly indicate that the national consumption patterns are important for the development of the industry. If firms within the industry are to expand in export markets, these national differences are important to take into account. In recent years barriers to free trade have decreased, better logistics and distribution systems have been developed, as have better methods for the preserving and packing of food and beverages. All these factors have eased consumer access to products from abroad and consequently the access created for foreign firms to national markets. But this is merely the physical access to markets: it is clear from the study that mental barriers also exist and persist. The historical, culturally rooted pattern of demand is of particular importance to this industry and indirectly influences the limits imposed on market innovation.

1.5 The importance of profitability for innovation

The market-driven development of the industry is further displayed in the relationship between innovativeness and profitability. At first sight, innovativeness and profitability seem unrelated at the firm level in this industry. This finding, however, conceals intra-industry and cross-country differences. The impact of innovativeness on profit varies depending on the home country in which the firm is based and on the phase of the business cycle. The most innovative firms persistently show the highest levels of profitability and least susceptibility to risk through critical phases of the business cycle. More importantly, they are the only ones to make profits above the norm continuously from 1977 to 1989. Conversely, the least innovative persistently display the lowest rates of profit. Profitability, for both firms and countries, emerges as being a function not only of using and developing advanced technologies but of orienting production to meeting changes in consumer demands.

1.6 National systems of innovation

The national innovation system appears from this and other studies as being of substantial importance. This finding may seem to contradict notions of globalization of production and technology, but the industry is heavily dependent on “external” sources of technology, such as suppliers and public laboratories, and turns out to draw most of its technology from local sources. This fits with what might be expected from a so-called low-tech industry. It could be argued that industries where innovations are heavily dependent on new scientific developments would be less reliant on the national innovation system - in particular those parts of the system which support research, general education, interplay between universities and industry, etc. However, the more informal institutions are important elements of a national innovation system, and are not necessarily related to high-tech industries. User-producer relations are critical to the generation and implementation of user-led innovations, and the technological trends towards increased complexity suggest that these are likely to become more important still in the near future.

1.7 Future development of the industry

1.7.1 Technological competitiveness of the European industry

From scrutiny of the patent data, analysed on country or regional bases rather than corporate ones, we can derive two broad conclusions for Western Europe. The first is that Western Europe has generally fared reasonably well in patenting in food and food-related areas. This has been associated over the period 1969-1994 with a strong performance in pharmaceuticals, and to the extent that pharmaceuticals act as a “paradigm” for the food-processing industry, that may be some comfort. However, in the light of broader analyses of innovation trends in the industry, and if new paradigms like biotechnology, electronics and instrumentation come to predominate in food technology, then West Europe’s broad disadvantages in these areas could become stumbling blocks.

1.7.2 The spread of industrialization in Europe: cohesion

The second conclusion is that food processing does have some inherent *a priori* advantages for disseminating industrialization across countries. Many currently advanced countries began their industrialization from strengths in this area. However, in recent times - at least so far as the patents evidence goes - these benefits have been reaped more by the medium-sized countries of Western Europe than by the smallest and most disadvantaged. The indications from our data are that the gaps are larger still in terms of implementing new technologies. Hence, while food-processing possesses many potential advantages for catching-up countries, much remains to be done to reap its benefits among the later developing countries. This may also be the case in Eastern Europe.

1.8 General policy implications

The general tendency in policy-making to date has been to emphasize the supply side. Thus, policies have aimed at supporting scientific discovery activities and at protecting the use of the results from widespread illicit copying. Such policy instruments include, for example, R&D subsidies, tax deductions on R&D expenditures, support to "high-tech" industries, funding of research institutions, and protection of intellectual property rights. In fact these instruments have been the main components in science and technology policy in the OECD area for the past few decades. The EU's recent *Green Paper on Innovation* if anything reinforces these patterns.

Our results strongly indicate that a shift towards the demand side is needed in policy-making at all levels: in firms, countries, and supranational bodies like the EU. This should also be accompanied by a shift in emphasis towards downstream technologies. The above-mentioned policy instruments are by contrast primarily directed towards supporting technological development upstream. Users, such as the food manufacturers, should not be seen just as the "problem" but as critical to the "solution". The focus needs to shift from knowledge creation to knowledge diffusion, but also from upstream to downstream in terms of the knowledge creation itself.

Recently policy-makers have recognized to a larger extent that knowledge creation does not take place in a vacuum but is strongly path-dependent and systemic, and that R&D is by no means the only input into the innovation process. We show in our policy conclusions that systemic learning is essential for the accumulation of technologies, and is most readily conducted at national or even supranational levels.

2. Introduction, general background

2.1 The importance of innovation for the industry

"Innovation is vital. It allows individual and collective needs (health, leisure, working conditions, transport, etc.) to be better satisfied. It is also central to the spirit of enterprise: every new enterprise is created through a process which is to some extent innovative. In addition, enterprises need to innovate constantly if they are to remain competitive."

The above are the opening lines of the *Green Paper on Innovation* published by the European Commission on 20 December 1995. The citation illustrates that in recent years the importance of innovation in competitiveness and economic growth has increased and so has the political awareness of the role of innovation in industrial development. As a consequence, policies aimed at supporting innovations have become still more important to policy-makers. Likewise the need for a better understanding of the innovation process is urgent in order to guide these policies and design adequate instruments. Unfortunately the statistics for displaying this process have been rather poor. Policy-makers to a large extent have had to rely on patent and R&D statistics - as output and input measures respectively - which do not capture the nature of the innovation process very satisfactorily.

2.1.1 The data for the study

The primary objective of this Report is to make use of the new dataset produced by the Community Innovation Survey (hereafter CIS), in order to give a much more complete picture of innovation in European industry. This dataset will be described more fully in Chapter 4. These studies are carried out under the EIMS programme (European Innovation Monitoring Studies) and the present study on Innovation in the Food Products and Beverages Industry is one of these studies.

As just noted, the statistics for measuring innovations have hitherto been rather poor. The Community Innovation Survey is focused directly on the innovation process and as such is one of the best data sources for analysis of innovation activities in the manufacturing sector. The data are based on approximately 40,000 answers to a harmonised questionnaire. The data do however have their limitations. One of these limitations is that we have data for only one year/period. Therefore, we use data from patent statistics when investigating developments over several years. Patent statistics have their limitations also. In particular, one would expect such data to be unable to capture all the incremental, downstream developments, as well as the less radical combinations of existing knowledge into new combinations. These features are typical characteristics of the innovation process within this industry. Consequently, we use CIS data to display these innovations. The preliminary conclusion from this short discussion about different indicators is that, because of the complex nature of the innovation process, a single indicator is unlikely to be adequate. Different indicators complement each other as they reveal different aspects of the innovation process.

2.1.2 The general importance of the industry

Studies in the member states and the preliminary analysis in the *Green Paper* suggest that innovation is very different across size-groups of firms and across industries. This is the background for a series of industry studies using the CIS data.

Several characteristics of the food and beverages industry make this inquiry into its innovation patterns of substantial importance. This is demonstrated by its quite considerable share in total manufacturing value-added in major countries - between 10% and 18% (see Table 2.1.1).

Table 2.1.1: Food, drink and tobacco, shares of value-added in all manufacturing, 1988.

Country	*Share in value-added, %*
Australia	17.8
Canada	13.4
Finland	11.9
France	12.4
Germany	10.3
Italy	10.8
Japan	11.5
Netherlands	14.8
Norway	18.0
Sweden	10.3
UK	12.8
USA	10.4

Source: Wyckoff, A. (1994), p. 75

Production of food, drink and tobacco accounted for 4.6 billion Ecus and employment for more than 2.3 million people in 1993. European firms tend to be highly competitive in the international market for food and beverages. The profit/turnover ratio of this industry is, moreover, very high at 7.7% in that year, compared with 5.3% for the chemical industry and 4.7% for automobiles. Furthermore, as this industry is an intensive buyer of inputs and equipment, innovative activity in food and beverages is likely to stimulate research in agriculture, chemicals, packaging, capital goods, robotics and so on. Finally, the analysis of innovation in food and beverages may be useful for understanding other traditional industries.

2.1.3 The incidence of innovation in the industry

Although often regarded as somewhat “low-tech” in relation to the scientific frontier, in fact innovation can make a valuable contribution to this industry

(OECD, 1988). The large relative size of the industry in EU countries makes this an issue of serious practical concern.

Table 2.1.2 shows the breakdown among innovating food-processing firms, in distinguishing those with innovations in the broad sense - that is products or processes new to the firm - and those with innovations in a more conventional sense - that is share of firms with innovations new to the food and beverages industry. The latter share is calculated both as share of all firms and as a share of innovating firms. The data are taken from the CIS dataset.

Table 2.1.2: Share of firms with innovations new to the firm and new to the industry

Country	*No. of firms*	*Innovating firms - new to the firm (%)*	*Innovating firms - new to the industry (% of all)*	*Innovating firms - new to the industry (% of innovating firms)*
Belgium	98	68	35	51
Denmark	85	58	34	59
Germany	115	77	18#	24#
Greece	34	68	n.a.	n.a.
Ireland	149	67	n.a.	n.a.
Italy	1481	31	15	48
Netherlands	221	66	24	36
Norway	173	38	27	71
Portugal	43	100*	40	40
Spain	279	35	n.a.	n.a.
All	2678	43	16	37

* The sample in Portugal consists of firms that are all presumed to be innovative.
# Not directly comparable

The general perception of the food and beverages industry is of a rather low-tech industry where those firms which do innovate tend to emphasize process innovations. What comes out of the table above are two things in relation to this established perception. First, there are actually large shares of firms who introduced innovations in the period investigated. This may relate to the fact that food and beverages firms are generally quite large, if indeed large firms tend to be more often innovative compared to small firms across the range of industries. However, we also see large differences among countries in the proportion of innovative firms in the industry. Italian, Spanish and Norwegian food and beverages firms generally have lower ratios of innovative firms than in other countries, though the Italian figure (especially) is undoubtedly affected by the large coverage of the dataset. Except for these countries there are actually high ratios of innovating firms in this industry. Calculations for the whole dataset without the country dimension show that on average 43% of firms are innovative in this industry. This is below the average for the whole manufacturing sector

(53%), but again that is partly accounted for by the Italian representation. Thus, if we calculate the total share of innovating firms without the Italian data we see that 57% of firms in the industry are innovative.

The above mentioned ratios of innovative firms refer to the definition of "innovative" employed in CIS - that is firms who introduce products or processes new to the firm itself. This definition includes therefore imitation. Taking innovation in a narrow sense the table illustrates that the share of innovating firms also differs across countries, but the ranking does not follow exactly the share of innovating firms in the broader sense. In particular, we see that firms in Norway and Italy - two of the countries with the lowest ratio of innovating firms in the broader sense - have a large share of innovating firms who introduced products new to the industry, whereas firms in The Netherlands tend to be more imitative.

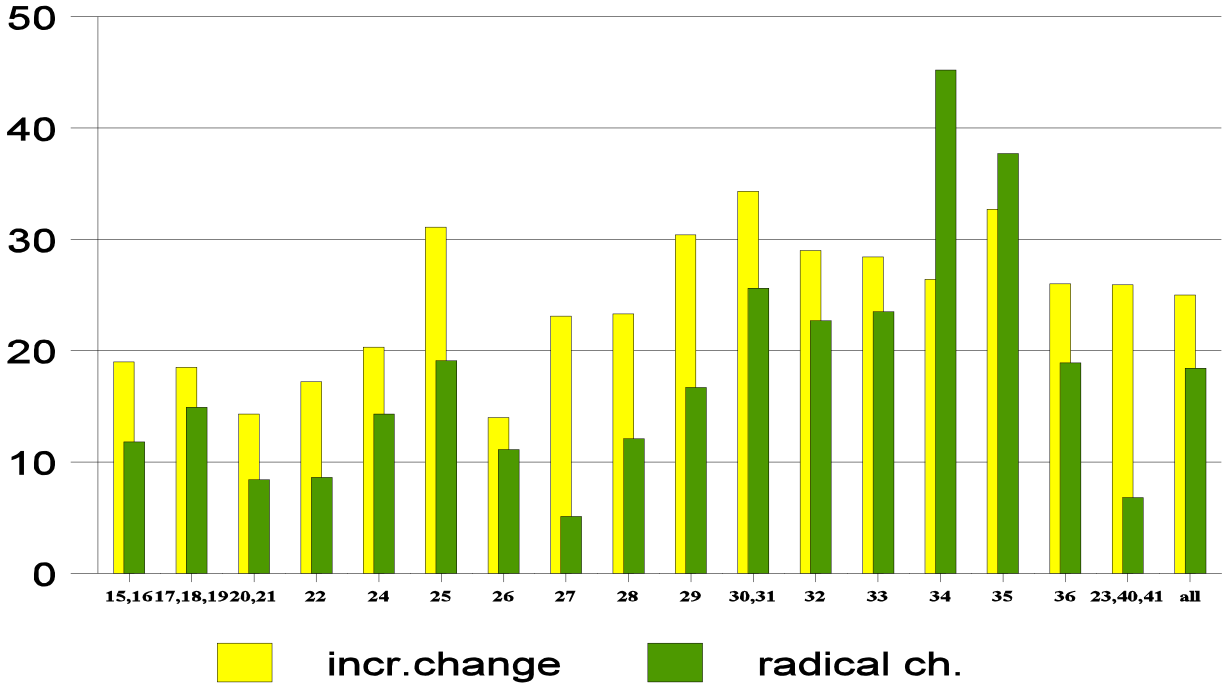
Second, an additional impression derived from analyzing the CIS data has to do with the alleged orientation towards process innovations. The data indicate a similarity between the share of product-innovating firms and process-innovating firms.[1] This may have to do with the size effect mentioned above: large firms are likely to have introduced both new products and processes in a three-year period. On the other hand the strong similarity may be (and probably is) an indication that product innovations and process innovations in this industry are interrelated to a large degree. This is plausible if we think of a firm that introduces a new food product: it is likely that such new products require some novelty in processing and/or packaging.

Comparisons with other industries are undertaken in Figures 2.1 and 2.2 by way of providing a context for the industry as a whole (compared to other industries) and for the subsequent study of its own innovation patterns. Figure 2.1 shows innovation output with respect to incrementally changed versus radically changed products. Figure 2.2 shows innovation output w.r.t. products new to the firm

1 In the PACE study it was found that results for patenting of products and processes are very similar - also compared to other industries (p.61).

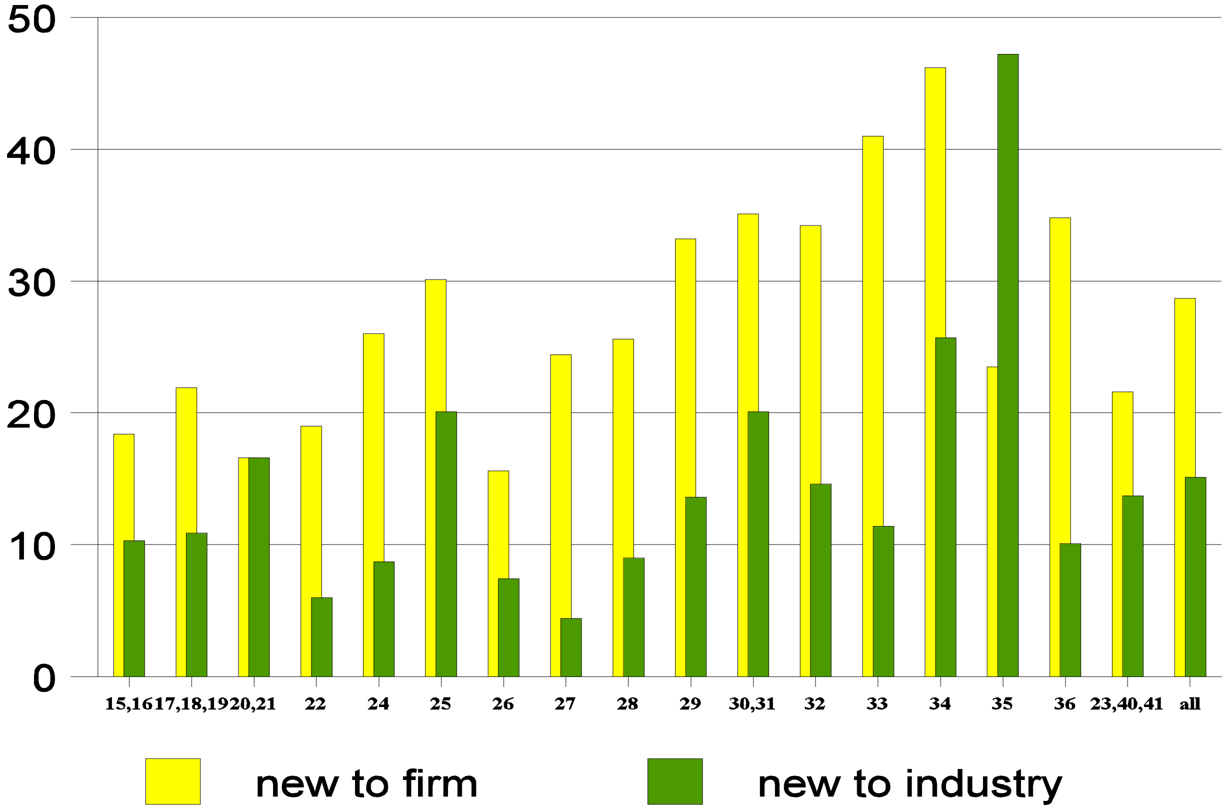
versus products new to the industry.[2]

Figure 2.1: Innovation output compared to other industries



[2] Based on CIS data and Calvert *et al.*(1996). The food and beverages industry includes tobacco here.

Figure 2.2: Innovation output compared to other industries



2.2 *The structure and development of the industry*

As a downstream industry, food manufacturing (including drink and tobacco) has traditionally been driven by market forces and product characteristics to a greater extent than high-tech industries such as electronics. Until recent times, the industry was regarded as one of a jumble of oligopolies, each firm of which would be competing for market share, using brand loyalty rather than product innovation as its main competitive weapon. With very stable products, technological development was oriented towards cost-cutting, mainly through mechanization and through substitution between materials. In more recent years, food manufacturing has come to feel some of the effects of technological revolutions occurring in some upstream industries, and is now receiving the impact of a whole range of new technologies, underlying which have been major shifts in consumer demand. Product changes and associated process innovation have characterised the recent state of the industry, as seen in Table 2.1.1 and as will be argued at greater length in Chapter 5 below.

As oligopolists, such firms typically struggled for market share, and very often this was construed as being obtained through the creation of brand names and of brand loyalties among their consumers. Brand names and the advertising that went with them were seen defensively as a guard against rapid erosion of market share by competitors, and sometimes aggressively as a way of driving competitors down. To a considerable extent, the pattern of takeovers and related organizational manoeuvres was determined by the quest for ownership of such brand names - to this day, corporations in the industry are often known much better by their stable of brands than by their corporate image (of course in some cases the two are identical, like the Coca-Cola Company).

Not only are the technologies of the industry demand-driven, but its organisation also reflects its downstream and market orientation. Large firms in the industry typically amalgamate several lines of business linked by a supposed market affinity, but often with little or no apparent technological connection. The technological structure of large firms is therefore highly differentiated. The firms may have another core competence in textiles (Sara Lee), construction (Hanson), toys (Quaker Oats), electricals (Ralston Purina), chemicals (Procter & Gamble, Unilever), glass (BSN), and so on.

The CIS data may also be used to illustrate some of the structural patterns of the industry. In total 2678 firms of the roughly 40,000 firms in the CIS dataset belong to the food and beverages industry. Table 2.2.1 shows the distribution of reporting firms according to size in full-time employees.

Table 2.2.1: Number of firms in CIS dataset and their size distribution

Country	*No. of firms*	*Size, employees mean*	*Size,employees, max.*	*Size,employees, min.*
Belgium	98	247	4404	4
Denmark	85	328	5850	40
Germany	115	628	16527	5
Greece	34	310	1853	13
Ireland	149	159	2833	10
Italy	1481	95	7030	3
Netherlands	221	525	43855	10
Norway	173	208	1653	2
Portugal	43	293	1614	3
Spain	279	208	1887	4

To give a background for the development of the industry up until the period covered by the innovation survey we briefly describe the re-organization of this industry taking place in OECD countries over the 1980s and early 1990s. On the demand side, the market for processed food has grown quite rapidly owing to significant changes in lifestyles and extensive advertising campaigns. On the supply side, the industry has changed in structure, showing increased concentration and capitalization in most developed countries. As food processors have been squeezed between controlled agricultural prices upstream and the growing power of retailers downstream, they have sought increases in scale. Another reason for pursuing large scale has been the attempt to spread fixed costs, such as advertising and R&D expenditures, over a broader production base (Connor and Schiek, 1996). The launch of a new product is now exceedingly expensive. For instance, it has been calculated that it costs US$ 30 million to launch a new product on the shelves of supermarkets in Europe's five biggest markets (*ibid.*). This interpretation implies that innovators would be inclined to a strategy for internal growth of their firms.

External growth has also been notable, especially at the end of the 1980s. Over the years 1985-89 alone, Rastoin and Oncluoglu (1992) identified 1567 mergers and acquisitions, joint-ventures and other structural manoeuvres among the world's 100 largest food-processing firms. The individual size of a number of these operations, often stimulated by financial speculation, has also been extraordinarily high. These combined internal and external strategies have helped promote industrial concentration in most advanced countries (McCorckle, 1988). The strategy adopted in the food-processing industry has tended to be one in which individual "lines of business" within each large corporation continue to maintain existing strengths, often with little technological link to other businesses in the company. The companies are instead more often held together by demand-side product-market interlinkages, of varying degrees of strength.

In addition, the evolution of profit has attracted new investors. Profit in food-processing is more resilient to fluctuations of the business cycle because the demand for food is less elastic to changes in income than the demand for other types of goods (Connor, 1983). This is a major reason why this sector was viewed as a stable, countercyclical industry during the various crises of the 1970s and 1980s. Profit rates that were higher than in most other manufacturing sectors (Marion, 1986; Dawson *et al.*, 1987; Alc and Bedetti, 1988; Nefussi, 1989) attracted important levels of investment from non-food industries, and from institutional risk-averse investors such as pension funds (Caswell, 1987). As a consequence, the funds available to firms expanded notably and the value of their shares rose throughout the 1980s. Vieille (1996) argues that high levels of profitability and liquidity helped account for the substantial external growth of European manufacturers in the late 1980s and early 1990s: of the 100 largest European manufacturing groups, food and drink (representing some 20% of the total) had the highest ratios of cash flow to value-added, along with the highest annual growth rates of the value-added.

The pattern of use of capital, labour, raw materials and energy also changed (Goodwin and Brester, 1995). In general, the food and beverages industry is erroneously believed to be labour-intensive. On the contrary, food-processing is one of the most capital-intensive industries in the US manufacturing sector

(Marion, 1986; Connor and Schiek, 1996). This trend was accentuated over the 1980s (Goodwin and Brester, 1995). Nefussi (1989) also points to the transition to "intensive accumulation" in French agro-industries over the late 1970s and early 1980s. Technological change contributed to greater substitutability between food inputs and non-food inputs (Goodwin and Brester, 1995).

The range of technologies on which food and beverages companies are drawing has greatly widened in recent decades, partly as the result of the emergence of new "technological paradigms", such as biotechnology and electronics (see Chapter 5 below). Confronted by such a world of growing technological complexity, the food manufacturers are either buying up research-oriented businesses or, more often, outsourcing the technological developments to independent firms (von Tunzelmann, 1996). Similar patterns seem to be emerging for some of the new research-intensive upstream industries (like biotechnology) in the modern era; though the Japanese companies appear to be heading in a different direction of focusing on applications and users. The food-processing firms are therefore still mainly dependent on suppliers, in conformance with the view of the industry as "supplier-dominated" (Pavitt, 1984), but the range of suppliers is widening far beyond the mechanical engineering industry on which it used to lean so heavily. In this manner, its feedback effects on innovation in supplier industries is becoming far more wide-ranging.

2.3 The research agenda

The food and beverages industry is generally taken as a "low-tech" industry. Nevertheless, as we have seen in Table 2.1.2, there is a substantial amount of innovation activity taking place.[3] After a short discussion in Chapter 3 on the theoretical background for the study we discuss the data sources used in Chapter 4. We next proceed in Chapter 5 to discuss in further detail what is the actual content of the innovation activity and what are the main trends and conditions for the dynamics of the industry.

In Chapter 6 we then investigate three sub-themes in greater depth at the firm level. The *first* is to investigate with CIS data what are the characteristics of leaders and laggards within the food and beverages industry. Firms are divided into three groups: the best performing third being the leaders and the worst performing third being the laggards. These three groups are mapped against some key indicator variables; namely export share, R&D intensity, innovation-cost intensity, turnover per employee, and share of new products.

The *second* sub-theme explored will be the role of strategies in explaining why some firms are leaders and others are laggards. The CIS data allow us to explore the different objectives of the two groups of firms in relation to, say,. size of firm. In this analysis the objectives of the firms are grouped in different ways, e.g. in

3 The *Green Paper* also concludes that industries usually assessed as low-tech may be highly innovative.

relation to product innovation, process innovation and market innovation. There is a particular focus in the investigation on whether a relationship exists between objectives and success.

The *third* sub-theme will be to have a closer look at the relationship between profitability and innovation. This requires a longer-term view and information on economic performance on the firm level. Both of these requirements cannot be fulfilled by using CIS data. Consequently patent statistics are used on a sample of large food and beverages firms.

A major objective is to analyse differences across countries in such behaviour. The country-level emphasis is maintained for three reasons: a) because of our view of the importance of national systems of innovation; b) because of its significance for policy-making; and c) more pragmatically, because of the country skew in responses to the CIS questionnaire (e.g. the disproportionately high response from Italian firms).

In Chapter 7 we move from the firm level to the interplay among firms and between firms and their surroundings. More specifically, we explore (mainly with CIS data) whether there is any importance attached by leaders and/or laggards to user-producer relationships and whether the national system of innovation is of major importance. User-producer interactions are not directly displayed in the CIS data. However, the section in the dataset on information channels gives us some indication. Thus, an emphasis on customers and suppliers may indicate a strong importance of user-producer interaction. Likewise, the notion of the national innovation system (NIS) is not directly addressed in the CIS data. Some indirect indicators are the importance of institutions in information sources and the share of firms who acquire and/or sell technology of certain kinds in the domestic market or abroad; also R&D collaboration with public institutions helps indicates the importance of the NIS. Some non-CIS indicators will be used as supplements.

Finally policy implications from the results are derived in Chapter 8, at the levels of the firm, the country, and the region (the EC).

The study is conducted jointly by IKE, Aalborg University, Denmark and SPRU, University of Sussex, England. Associate Professor Jesper Lindgaard Christensen participated from IKE and coordinated the project. Dr Nick von Tunzelmann participated from SPRU, working with Dr Ruth Rama, of CSIC, Madrid.

3. Theoretical background

No empirical study or collection of data is totally devoid of theoretical and conceptual foundation. The specific types of data collected, the way the data are collected, the way the concepts are defined, and the way the data are afterwards used, all reflect certain *a priori* perceptions of what the data are supposed to reveal.

In the following the theoretical foundation for the analysis is outlined.[4] The discussion is kept on a general level, with a separate discussion (in Chapter 5) being devoted to the specific characteristics of the industry. Thus, following the general outline of research questions specified above, the theoretical background will deal in turn with general innovation theory, strategy, the relationship between profitability and innovativeness, user-producer interaction and learning and national systems of innovation.[5]

3.1 Theory and the innovation process

In the minds of many people, and in many innovation studies, innovations are associated with radically new products. Thus some studies focus on visible, radical innovations like computers, synthetic materials, etc. However, the physical end-product is only the tip of the iceberg. In fact, the major resultant innovations are the outcomes of a long process, which is characterized by much more gradual modifications than the impression obtained from focusing on end-products.

The term "end-product" is not that fortunate because even after commercialization modifications continue, as feedbacks from users, sales offices, competitors, etc. are important inputs to further development of the product. Kline and Rosenberg (1986) emphasize this perspective by developing a so-called chain-link model of the innovation process as an alternative to the traditional linear model, which had seen the process as a continuous, progressive development from research through development and production to marketing. As opposed to that model, the chain-link model emphasizes feedbacks which help to formulate how to proceed. In particular the model suggests that innovations are often the results of interaction between market opportunities and the knowledge base and resources of the firm. This model seems compatible with the "dynamic capabilities" view of the role of the firm, as espoused in some recent literature (Teece and Pisano, 1994); in which

4 Among the many sources for this Section should be mentioned Smith (1994) and Archibugi *et al.* (1994).

5 These are broad topics and the discussion that is to follow is intended to be illustrative and focused, rather than exhaustive. For an account of the development and state of the art in the economics of technological change see Freeman (1994).

existing resources have a major guiding influence on its development, but also interact with external developments in markets, technologies, finance, etc.

These two properties - the gradual modification of products and processes and the interaction with the market in this process - are especially important in the food and beverages industry. In particular, they are important parts of the theoretical background for two of our claims in this Report. The first of these is that the traditional perception of the industry as being low-tech may seem true if measured only by R&D intensities and patents, but in fact the industry may still be rather innovative, through such gradualism and diffusion in the innovation process. Minor changes of products and processes and combinations of existing knowledge require R&D to a lesser extent and are less likely to be patentable compared to more radical innovations in some of the industries traditionally assessed as high-tech. The second claim referred to has to do with another traditional view on the food and beverages industry: that the industry is particularly process-oriented. As will be argued in more detail later, the response from the market is very important to the innovation process within the industry.

Thus, we see innovations in food and beverages as results of an open-ended, evolutionary process, which makes it hard to date the start and end of an innovation in time and to see it as a single event. Innovations are often a result of small deviations from everyday routine activity and are often created by new combinations of existing knowledge. This suggests that many innovations, even the more radical, involve elements of incrementalism, and learning is a central characteristic of the process. Application of an existing product, process or new knowledge to a new area may yield great effects and may contribute to further modifications of the original innovation. In food and beverages this has indeed been the case, as witnessed by the immense effect of developments within packaging.

3.2 Innovation strategies

In a rapidly changing world the opportunities for firms to develop successful innovations are not random but follow certain historically circumscribed lines with respect to technological, market and financial developments. The ability and willingness of firms to adapt to the changing environment are not random either. Within the limits indicated above, the single firm faces choices among the range of alternative strategies for survival and growth, choices which are often vital for the future of the firm. This is the rationale for investigating the role of innovation strategies of food and beverage firms.

Discussing strategies for firms and the effect of such strategies may sometimes be a rather difficult task, because they are not always easily identifiable and their influence may likewise be hard to detect. Nevertheless it is useful to have a framework or a typology of strategies before trying to investigate what their effects might be. The picture becomes blurred by the fact that there may exist different strategies in the same firm at the same time, because some products may be developed with one strategy and some with another. Furthermore, one strategy may be adequate in one branch of industry and not in another, not to mention in one country compared to another.

Further complications could be added. For now we shall use as a tool for analysis an elaboration of a well-known typology in line with Freeman (1982, p.163) and Kay (1988, p.288) (who adopts Freeman's framework).

In spite of all the cautions about defining strategies and identifying them with CIS data, some effort is made to use the data to separate firms with different strategies in accordance with the above-mentioned typology. Several different parts of the questionnaire may be used for this purpose, as is illustrated below.

Table 3.2.1: Strategy identification and CIS data

Strategy	*Offensive*	*Defensive*	*Dependent*	*Imitative*
Importance of R&D	large	large	absent	absent
Importance of Product-/process	product	product	product	process
Sources of innovation	internal, research institutions	competitors	costumers-/clients	competitors/ general available information
Extend product range	yes	yes	within main field	yes
Acquisition of technology	results of R&D	licensing, hiring skilled employees	acquisition is from mother enterprise	
Transfer of technology	licences, R&D performed for others		sales of equipment	none
Appropriability	patents lead time			
Develop products new to the industry	yes			no

Note: the strategies are those readily defined from the CIS data.

Some of the above variables are more obviously related to a particular strategy than others. In practice some will be combined so that only one of the data variables in a group - or more than one group - of variables should be rated highly whereas others are mandatory. For example, it could be argued that a firm with an offensive strategy must develop products new to the industry, but the kind of transfer of technology could be either "licences" or "R&D performed for others". This will complicate the picture, but still the strategies may be possible to identify.

3.2.1 Offensive product development strategy

An offensive innovation strategy may be suitable when there are large advantages of being first into the market. The strategy aims at getting technological and market leadership. Using this strategy a long time-horizon is often necessary, and this enhances the danger of irrelevance of the product when it finally becomes ready for introduction. By then, a competing or similar product may have established market dominance or the conditions in the market may have changed as a result of public regulation, changes in consumer preferences, etc. Therefore, property rights and lags in competitive responses and imitations are important factors to take into account when deciding on this strategy (Kay, 1988, p.288).

An important prerequisite for this strategy for the firm is either its own research and development department or easy access to relevant basic research. This enables the firm to develop products from ideas generated internally, but also to incorporate externally generated knowledge into the product development.

3.2.2 Defensive product development strategy

Following this second strategy a firm may be able to eliminate some of the large uncertainties “upstream”, by developing or redesigning products which have been introduced by others. Firms may thus accept to be behind the first-comer firms but not too far behind. The nature and timing of innovation is somewhat different from the offensive firm but this is deliberately chosen, in order to benefit from mistakes made by first-mover firms and to react to responses from the market. This is not to say that this strategy does not involve R&D and is costless. In fact, it is often necessary to maintain a large knowledge base in-house precisely in order to be able to respond quickly to actions taken by competitors, such as successful radical innovations. Typically the defensive firms emphasize product differentiation. This enables them both to maintain a non-specific knowledge base and to utilise the differentiation of products as a kind of insurance against market fluctuations.

3.2.3 The dependent strategy

Some (especially small) firms may choose to be linked to a larger firm, group of firms or government institution. Such firms, often sub-contractors, usually make only minor, incremental innovations, often at the request of the dominant firm, or they adjust to changes in specifications. Thus the responses from customers are vital as information sources for innovations. R&D is most often absent in firms following this product development strategy. If the firm uses R&D it is often not in-house but most likely based in a parent-firm.

3.2.4 The imitative strategy

Imitators rarely introduce more radical innovations but try to produce new products developed by others, either by utilising cost advantages (labour costs, material or energy costs) or by taking advantage of being in a specific market, through having superior distribution or marketing facilities, or benefits from special legislative conditions or public sector demand, etc. To enhance such cost advantages, process innovations are ranked relatively higher than product innovations compared to the priorities in firms following the other strategies.

R&D is limited but on the other hand imitators must keep up with technical information sources in order to know about optimal production techniques and potential products or process techniques worth imitating.

3.3 Profitability and innovation

Intuitively it would appear that one of the primary driving forces for innovation is the search for profits, as innovation and risk have traditionally been associated with above-normal profits. Other influences and multiple interlinkages however complicate any attempt to draw simple statistical conclusions.

3.3.1 Impact of Innovation on Profit

Although, in most cases, the results reached by different empirical studies show positive associations between innovation and profitability, there is some divergence in research outcomes.

First, the association of innovation and profitability is more complex and difficult to measure than often imagined (Rosenberg, 1982). The extent to which innovation can increase profits depends on some rather diffuse interconnections, with innovation having both direct and indirect effects on corporate profitability (Cohen and Levinthal, 1989; Geroski *et al.*, 1993). Direct effects include the classical influence on profit via market share; indirect effects include improving competitive advantages in a variety of forms (Geroski *et al.*, 1993), with examples including the building of core competencies and the ability to imitate new products or use new equipment. Although less explored, innovation may also have an impact on financial aspects, which in turn can affect performance. Projects launched by successful innovators, for instance, may inspire confidence on the part of investors or financial institutions (Chaney *et al.*, 1991). This situation is likely to alter financing methods, with indirect effects on the rate of profit.

Effects of innovation on profit are probably even more diffuse when the ratio of R&D to sales is small, as in food and beverages. Therefore, we do not expect linear models would give full account of the influence of innovation. On the contrary, we undertake a complex analysis in which a variety of both financial and technological factors will need investigation.

Second, evidence suggests the effects - especially direct effects - of innovation on profit are likely to be small, even in high-tech industries. Branch (1974) found a positive association between the number of patents per unit of assets or profit in 111 firms related to seven US industries (food-processing was excluded). Yet his chi-square coefficients for innovative output are small, indicating limited effects. Geroski *et al.* (1993) also found a positive association between commercially significant innovations and profit margins in a sample of large UK firms. However, increases in profitability were modest in most industries and, moreover, negative in food and beverages.

One further reason to expect small direct effects in food and beverages is that the period for the innovator to obtain monopolistic gains is short, because most new foodstuffs are easy to imitate (OECD, 1988). Expectations of direct effects could probably be described as an "investment in roulette" (Bowman and Asch, 1987). In many cases, however, innovation could have a subtle, indirect effect on variables affecting the rate of profit, and probably the path to it. In a study of 17 US pharmaceutical firms, Narin *et al.* (1987) found high correlations between an estimated financial factor and specific patents denoting originality or quality only.

Third, another area where authors disagree is over "reverse causation", i.e. profit rates affecting subsequent R&D. Most studies have taken such a possibility to be remote, but an exception to this general view is provided by Grabowski (1968), who investigated R&D expenditures relative to sales in 41 large US firms. Others believe that, although profitability and liquidity may determine innovation in small firms, these variables are not particularly relevant in large companies, who usually produce enough internal funding to finance innovation (Acs and Isberg, 1991a; Himmelberg and Petersen, 1994); whereas the R&D budget of small firms is more subject to economic fluctuations (Kay, 1979). After a review of the literature on this topic, Kamien and Schwartz (1975) concluded that "the empirical evidence that either liquidity or profitability are conducive to innovative effort appears slim". These results have a methodological interest for our research, in which the causal direction that is studied is the influence of innovation on profit, and not the other way around.

3.3.2 Capital structure

The Modigliani-Miller Irrelevance Theorem concluded that the financial structure of a firm was irrelevant to both its value and its operating decisions (Copeland and Weston, 1992). However, Acs and Isberg (1991b) found capital structure may be a determinant of innovation: in large firms, innovation tends to be financed by equity, and in small firms by debt. Santarelli (1991), who reaches similar conclusions, explains that in large innovative firms, directors would increase equity as a signalling device to attract new shareholders. In addition, indebted organizations are not likely to promote projects involving additional risk, which is often the case with new technology (Bowman and Asch, 1987). Moreover, the development and sagacity of financial institutions influence innovation in industrial firms (Dosi, 1990; Sweeting, 1991; Prakke, 1988).

According to such theory, an increase in gearing would discourage innovation while an increase in equity would stimulate it. These considerations are also meaningful because firms based in different home countries deal with different types of financial systems and divergent institutional arrangements. A number of Japanese and French food and beverages firms, for instance, are able to internalise finance because they are protected by large groups including banks. These firms are more efficient regarding funding than independent firms (Galliano, 1991; Galliano and Alcouffe, 1993; Hoshi *et al.*, 1991).

3.3.3 Size and Innovation

As will be seen in later chapters, firms from different countries have different average size. European firms, for instance, tend to be smaller than US firms. How will these situations affect innovation? Schumpeter came to believe that large firms, with monopolistic market control, would be especially prone to innovate. Results of empirical tests are contradictory, however. Audretsch and Acs (1991) attribute these contradictions to different measures to quantify technological change and the exclusion of small firms from the analyses. These authors found a U-shaped relationship between firm size and innovative intensity, i.e. innovations per employee, in a sample of innovative firms of different sizes. Based on that standard, the smallest firms are the most innovative-intensive and the largest firms produce the fewest innovations per employee. Audretsch and Acs admit, however, that the innovative intensity of smaller firms is reduced if one includes non-innovative firms in the sample. In other words, the orthodox results as in the later Schumpeter are more accurate when both innovators and non-innovators are represented. This methodological point is adopted in the present study: our samples include both innovators and non-innovators.

3.4 The importance of knowledge and users

Many studies have indicated a relative shift in recent decades from tangible capital towards intangible capital, i.e. from physical capital formation towards human capital formation or knowledge. Modern innovation theory has recently explored the concept and use of knowledge in depth. According to Dosi (1988, p.224), knowledge is a precondition for solving an innovation problem, and it has at least three dimensions: it can be articulated versus tacit, public versus private, universal versus specific. In our view the relevant knowledge for innovation in food and beverages is most often tacit, cumulative and idiosyncratic.

It has been recognized that different firms use different kinds of knowledge bases with different degrees of specificity. This specificity may relate to the society level, the industry level, or the firm level. At the level of the firm, the specificities of the firm with respect to competencies, strategy, capital equipment and organisation determine what kind of knowledge base is used. Depending on the size of the firm, the knowledge base may even be specific to one or a few individuals within the firm. At this level knowledge in innovation is thus primarily specific, tacit and private.

Although it is possible to make the distinction between different types of knowledge bases, the division is of course to some extent academic rather than practical. In practice the different types of knowledge are interrelated and integrated in complex ways. Likewise, their development is not separate but comes about through an interaction between firms and institutions. This interaction mainly takes place in a national context even though some knowledge is created abroad and transferred across borders through research institutions, multinational firms, etc. Increasingly, knowledge bases are international rather than rooted in a national context. But still there are debates about why national borders matter as a framework for the creation of knowledge. These arguments are mainly related to what facilitates interaction, like language, proximity in geography and culture, and collaboration with research institutions, but also to common standards and legislation, limited cross-border mobility of the labour force and the national character of the technological infrastructure and policies. All of these are important arguments why nation-states matter in technological development and knowledge creation.[6]

The discussion above indicates that technological knowledge should be seen as systemic. Thus, the knowledge bases are highly dependent on some form of institutionalization if they are to be stable. One could argue that firm-specific technological knowledge may be more volatile. But even at the firm level, innovating firms are likely to be dependent on what in recent innovation theory has been labelled the innovation system. This goes along with their search for new, necessary technological knowledge, with the assessment, implementation and use of this knowledge in the firm, and with the need for external aid in the innovation process. An additional argument only indirectly related to the creation and use of technological knowledge is that firms are often dependent on the financial system, the education and training system, the public procurement and industrial policy, and legislation like standards, environmental regulation, etc.

The innovation process is complex and the timing of innovation is extremely difficult - and increasingly so because the “market window” is rarely open for very long; the imitation process being fast because of the generally higher level of information on competitors and because costs of breaking down entry barriers in food and beverages are high. Therefore, the performance of an innovation system is not solely dependent on knowledge creation and not on the single institution in the system. Rather it is dependent on the systemic ability to learn - that is the institutionalization of knowledge created through interaction between institutions and firms and among firms. In other words, the evolution of knowledge-creating and diffusion systems is essential to industrial development. The performance of the innovation system is also dependent on the ability of the system to provide the right kind of information and knowledge to firms at the right time. This ability

6 For an elaboration see Lundvall (1992).

will in turn affect the costs of innovation efforts at the firm level and the amount of imitation at the level of society at large.

3.5 Implications for innovation measurement

From the above we hope to have made clear that the innovation process is complex in several different ways. For example, the inputs to the process may vary from institutionalized, planned basic research to on-the-spot, incremental changes of product or process. The output from the process may likewise take several forms and is in many cases difficult to locate precisely in time. We have also discussed knowledge used in such processes and emphasized the many different kinds of knowledge, including the powerful role of tacit (non-codified) knowledge.

The implication for innovation measurement is that a single measure is unlikely to capture all the relevant aspects of the innovation process. One must therefore be aware of the limitations of using only one indicator and we have in this study supplemented CIS data with other indicators. Even when using several supplementary indicators it is not possible to cover all of the innovation process. In other words there are aspects of innovation on which we do not yet have adequate indicators. Even on specific issues where e.g. CIS data are appropriate, there are limitations to the measurement of innovation.

4. Data sources and the industry

4.1 General information on the CIS

The background for the CIS project is a set of mostly independent surveys on innovation carried out in the 1980s. The experience from these surveys resulted in an OECD manual in 1992 (“OECD Proposed Guidelines for collecting and interpreting data on technological innovation” - the Oslo manual) which is intended to be a basis for more coherent future surveys. The manual is currently being revised. Eurostat and DG-XIII developed the CIS in collaboration with independent experts and the OECD, resulting in the final, harmonized questionnaire in June 1992. The objective of the CIS is

> “to collect firm-level data on inputs to, and outputs of, the innovation process across a wide range of industries and across Member States and regions, and to use this data in high-quality analyses, which among others, will contribute to the future development of policies for innovation and the diffusion of new technologies at Community, Member States and regional level”.

The CIS, or closely similar, approach is also implemented - or is planned to be implemented - in some non-member states. This goes for Canada, USA, Norway, Finland, Austria, Australia, and South Africa.

The database contains a large variety of variables on innovation in approximately 40,000 firms. Item-non-response has been estimated, weighting factors applied, and logical checks conducted. In addition, a so-called micro-aggregation has been undertaken. The purpose of this modification is to anonymise the data while retaining the maximum of information. The method used for the micro-aggregation depends upon the nature of the variable. The basic principle in the modification is that observations are grouped by three and each observation is replaced with the cluster arithmetic mean.

Table 4.1.1 gives a list of the groups of variables in the questionnaire.

Table 4.1.1: Variables in the CIS questionnaire

Variable group	*Examples of variables/sub-groups of variables*	*Type*
General information	Number of employees, turnover in 1990 and 1992, innovative vs. non-innovative	metric, binary
Sources of information for innovation	Internal sources, external/market sources, educational/ research establishment, generally available information.	ordinal
Objectives of innovation	Replace products, extend products, new markets, lower production costs	ordinal
Acquisition/transfer of technology	Licences, consultants, purchase/sale of equipment, skilled employees, R&D, communication with other enterprises; all variables broken down on geographical bases	binary
Appropriability	Patents, design, secrecy, lead-time advantages, complexity	binary
R&D activity	Expenditure on internal and external R&D, plans for R&D, cooperation with different partners broken down on geographical bases	binary, metric
Factors hampering innovation	Economic factors, enterprise factors	ordinal
Costs of innovation	Current expenditures, broken down into R&D, acquisition of patents and licences, product design, trial production, market analysis, capital expenditures	metric
Impact of innovation activities	Distribution of sales by product stage, degree of change of products, export sales, products new to the industry	metric

The questionnaire is aimed at enterprises within manufacturing and is generally sent to a stratified sample of enterprises with relatively low cut-off points. The CIS was implemented for the first time in the autumn of 1993 and asked for information on innovation activities in the period 1990-92. As such the CIS may be seen as a pilot project, and experience from the first implementation is valuable in relation to a future survey. Use of the data for purposes of comparing across countries is still restricted to some of the countries because of differences in sample, questions and implementation methods in the member states.[7] Some of the questions asked are quite new to the firms and consequently answers on those questions are generally less precise. This goes in particular for the questions on innovation costs and the distribution of sales according to product life-cycle stages. These questions are also among those frequently left blank by respondents.[8] In the micro-aggregated database this item-non-response problem is dealt with by means of estimations of the missing values. Different estimation techniques have been used for different types of variables. Behind the estimations lie assumptions about relationships between the variables in the CIS dataset. It could therefore be questioned whether such estimations are necessarily beneficial for the dataset. In a way a theoretical construct is imposed on the data,

[7] See the evaluation reports by Archibugi *et al.* (1994) for an in-depth assessment of the data quality as well as the implementation in each member state.

[8] One country's evaluation reckons the time used by respondents to fill in the questionnaire to be on the average 120 minutes, ranging from 60 to 210 minutes.

which were supposed to be neutral. On the other hand, the number of observations are increased in this way. It has therefore been decided not to exclude the estimated values from the database.

Even if there remains much to be done in terms of improving implementation of the surveys, the CIS does have some advantages. The data are directly focused upon innovation, and they are to a large extent comparable across countries, industries or other types of aggregations. The number of observations is relatively large. In addition, they are firm-level data, which makes it possible to link innovation to other data on firms.

However there are also weaknesses of the CIS data. For example much progress is still needed with respect to coverage of the data. Some of the most important players within certain industries are not in the database. This goes not only for the USA and Japan, which is to some extent natural in a Community-based survey, but it also goes for some of the major European countries, both those covered by the survey and those not surveyed. Later in this report we shall provide evidence from patent data which shows that in food and beverages Switzerland, France, the UK and Sweden are some of the major countries in this market, whilst these countries are not covered satisfactorily in the CIS. Another weakness is differences in the implementation of the survey across countries. In spite of efforts to harmonize the questionnaire and sampling, several of the member states did not follow the instructions, with the result that some questions and even datasets are not comparable. So even if we regard the cross-country comparability as one of the strengths of the CIS, we must also point to the difficulties in comparisons across countries. Among the drawbacks it should also be mentioned that the survey is rather biased towards product innovation, whereas process innovation is treated in parts of the questionnaire only. The many variables in the CIS provide many possibilities for interesting analyses. We do, though, have data for only one year, which makes it difficult to draw robust causal conclusions as to what is best practice in innovation. Many more weaknesses could be mentioned (the focus upon manufacturing, the data covering just a recession period, etc.), but the critique should not overshadow the fact that the CIS provides one of the best data sources for mapping the nature of the innovation process in manufacturing compared to other data available.

The CIS is therefore an important data source in this study of the food and beverages industry but in some sections other data sources are included as well. Thus for some purposes we use patent statistics, as described in the next section.

4.2 Patent statistics

Since the CIS data do not allow us to inquire into the important topic of profitability and innovation (discussed in theoretical terms in Chapter 3 above), we have used alternative data sources for this purpose.

A sample has been constructed comprising 101 food and drink multinationals with average worldwide sales of at least US$ 1 billion in 1988 (Appendix 6.1). This is described in Section 6.3.3 below. As the relationship between economic and technological variables may vary over different phases of the business cycle (Narin *et al.*, 1987) we analysed three subperiods: 1977-81, 1982-85 and 1986-89. The first is a period of expansion, while the second is a period of crisis and the third witnessed recovery in this industry.

4.2.1 The Method for Measuring Innovative Output

We use the count of patented inventions, i.e. patents granted to the firm in the United States, as a proxy for innovative output. We have analysed utility patents only in this study - “design patents”, which involve minor changes in presentation or packaging, are not included here.

This method for measuring innovative output has certain drawbacks. Patent counts give no information on the technical importance or the market value of innovations. Not all inventions are patented. Many successful innovations are actually never patented (Rosenberg, 1982). Some types of technology are more likely to be patented than others (Acs and Audretsch, 1989). Likewise the propensity to patent differs across industries. In particular, in the food and beverages industry, the downstream, incremental innovations are not patented to the same extent as more upstream industries. This result is found in the PACE study, which also finds a general association between R&D intensities and propensities to patent. Furthermore, firms from different countries have different propensities to patent their inventions (Archibugi and Pianta, 1992; Scherer, 1989) and/or different propensities to patent in foreign countries.

Some of these objections lose their importance in homogeneous samples, such as that in this study. Enterprises with similar sizes, businesses and so on, are likely to show similar patenting behaviour (Branch, 1974). Multinational firms, like those in our sample, are likely to globalize their strategy for protecting their intellectual property and exhibit similar foreign patenting patterns (Archibugi and Pianta, 1992). Nevertheless, comparisons between US and non-US firms should be treated with some caution. The latter firms presumably patent their inventions in the US in proportion to their business involvement in that country. On average, non-American firms would expect to patent fewer inventions in the US than American firms of similar size, because of the fact that the former firms enjoy smaller market shares in the country.

On the other hand, a number of empirical studies support the idea that patents reflect with some accuracy other manifestations of technological change. Acs and Audretsch (1989) found a strong association between direct measures of innovative activities and the number of patented inventions at the 4-digit standard industrial classification (SIC) level in US manufacturing. Bound *et al.* (1984) had previously established a strong relationship between R&D expenditures and patenting activities at the firm level in the US. The association between R&D expenditure or patenting, on the one hand, and significant innovations, on the other, seems to be clearly established over longer periods of time. Cumulative curves of patents and innovations at the firm level are more likely to be compatible over longer periods of time than on a year-to-year basis (Achilladelis *et al.*, 1990). The correlation between R&D spending and total number of subsequent innovations is more clearly observed over the long run as well (Mansfield, 1968). For these reasons, this research covers a period of 12 years.

4.3 Identification of the industry

The Food and Beverages industry consists of nine subgroups at a 3-digit NACE level:

15.1 Slaughtering, processing and preserving of meat and meat products
15.2 Processing and preserving of fish and fish products
15.3 Processing and preserving of fruit and vegetables
15.4 Manufacturing of oil and fat
15.5 Manufacturing of dairy products
15.6 Manufacturing of starch and starch products
15.7 Manufacturing of fodder
15.8 Manufacturing of other food products
15.9 Manufacturing of beverages

It could well be that innovation activity differs substantially across these sub-groups. If that is the case, consideration should be given to using more disaggregated data than the 2-digit data, which are what we have in the CIS dataset.

Using the original Danish dataset we took a closer look at the degree of homogeneity within the industry. Results for several variables were compared across sub-groups:

1 Share of innovative firms
2 Share of firms with R&D
3 Share of firms with products new to the industry
4 Average R&D intensity
5 Average innovation-cost intensity

As we have access only to the Danish dataset, it is assumed that approximately the same degree of difference would occur across subgroups in the other countries. It could, of course, be questioned whether this assumption is realistic. Especially in this industry an above-average degree of specialization is likely because certain areas of production are dependent on geography and climate. On the other hand, a considerable range of variables is included and Denmark is one of the larger food and beverages producers.

Table 4.3.1: Selected variables distributed by subgroup in the Danish CIS dataset

Variable*:	1	2	3	4	5
Subgroup**:					

15.1	24 %	21 %	3 %	0.06	0.15
15.2	39 %	20 %	5 %	0.19	0.33
15.3	50 %	36 %	7 %	0.23	0.38
15.8	56 %	46 %	15 %	2.48	0.81
15.9	45 %	10 %	10 %	0	0.07

Notes: * Variables and sub-groups are as defined in the text above;
** The number of observations in sub-groups 15.4-7 is too low to be reliable.

The sub-branch 15.1 (Slaughtering, processing and preserving of meat and meat products) appears somewhat behind the other sub-groups technologically. This also goes for 15.2 (Processing and preserving of fish and fish products) but to a lesser extent. At the other end of the spectrum we find 15.8 (Manufacturing of other food products) which is particularly innovative. The results for the other sub-groups are around the average. These results are broadly consonant with sub-sectoral data on innovative variables more generally, across countries - see for example the patents data in Section 7.3 below.

The pros and cons of further disaggregation can be summarized as a trade-off between a better description of the diversity of the innovation process across branches, and fewer observations in the calculations. The implication to be drawn from the above is that further disaggregation of data is not really needed. Although we could detect some differences across sub-branches, these differences were not so great as to warrant a disaggregation which would reduce the number of observations in the calculations and maybe blur some of the patterns in the results.

With respect to the countries included, we do not have enough observations in the dataset to produce meaningful results for Luxembourg, France or the UK. When using non-CIS data we shall include these countries and pay particular attention to results from these analyses. In some of the other countries there are only a few observations when the analysis is narrowed down, e.g. to sub-divisions of R&D-performing firms or R&D-collaborating firms. Some of the analysis could be carried out without the country dimension in order to keep the number of observations at a maximum, but for reasons mentioned earlier the results here are divided into different countries.

Throughout the study of this industry different methods of analysis have been used, depending on the issue explored. As explained earlier, the analyses using the CIS data are carried out for each country, which makes for some complexity of the exposition of results. The intention is to keep the results as simple as possible in spite of the country dimension. We shall therefore primarily report descriptive statistics in tables and explain results from other types of tests verbally. Some of the results are however reported in other forms. Generally only statistically significant results are commented upon unless otherwise indicated.

5. Trends in innovation in the industry

Traditionally the food-manufacturing industry has been regarded as rather minor in terms of its role in technological and economic development. Students of both innovation studies and economics have been more attracted to the "high-tech" industries, where the role of science and technology has been more apparent. It is arguable that this has always been something of an oversight: for example, the early stages of industrialization in a number of European countries (including Denmark, Netherlands, Switzerland) were profoundly influenced by the technological and economic advance of food manufacturing (von Tunzelmann, 1995a). There is even less good reason to support the neglect of the industry nowadays, for reasons to be detailed below, but there is little sign as yet of any widespread appreciation of this situation.

We shall argue in this overview that the food-processing industry may become one of the major "carrier" industries of the current phase of industrialization, known to some scholars as the "Fifth Kondratiev" (Freeman and Perez, 1988); though other industries are likely to share this role. This "wave" has been sustained by dramatic technological change in upstream industries, most notably electronics; more recently, areas like biotechnology and advanced materials have emerged as high-tech fields with massive opportunities in prospect. The role of the "carrier" industries has been less extensively analysed. Their function was first elucidated by Rosenberg (1963) in studying the machine-tool industry in America in the nineteenth century. The carrier industries were downstream consumer-oriented industries which embodied the advances carried out upstream in the machine-tool sector. In these industries, consumer demand confronted the supply of technologies, and the latter - the types and capabilities of the machine tools themselves - were changed both radically and incrementally to suit the needs of the former. Typical carrier industries for machine tools in the nineteenth century were, successively, clockmaking, sewing machines, bicycles, and eventually automobiles (Rosenberg, 1963). From these downstream applications and modifications, the machine-tool industry itself found it straightforward to extend those changes to a host of other applications in less progressive downstream industries, adopting much the same principles for different users (Rosenberg described this as "technological convergence").

5.1 General Background

We consider that food processing and packaging may well act in similar vein as a carrier industry in the foreseeable future. Of course we do not claim it will be the only carrier industry; far from it. But the potential, in our view, has been largely ignored. One facet of this has simply to do with sheer size. The upstream and high-tech industries are characteristically of rather small size relative to the economies at large. This was true of machine tools throughout the nineteenth century, and remains true of biotechnology etc. today (though not true of electronics). Although their technological role is crucial, their economic impact will not be so great until their advances are embodied in a wide range of comparatively large downstream industries. The diffusion process involved has typically taken a whole "Kondratiev cycle" to effect (von Tunzelmann, 1995a). An implication is that the periods of technological ferment may not be ones of major economic expansion, and this appears to be one important explanation for the "productivity paradox" of slow economic and productivity growth since the 1970s in the "Fifth Kondratiev", notwithstanding the evidently dramatic transformation of industries such as information technology in that recent period. On the basis of analogies with the past, it will require a "Sixth Kondratiev" of massive downstream applications to induce a macroeconomic effect of major proportions.

Let us now examine why the food and beverages industry would appear to possess some of the attributes required of an important carrier industry in any forthcoming "Sixth Kondratiev". Clearly it has the size attribute, as shown in the data on the industry's size provided earlier in this Report (e.g. Table 2.1.1). Its rate of growth has been regarded as more problematic. The consumption of food has traditionally been subject to "Engel's Law", first elucidated in the 1880s; that as incomes go up, the share of food in total expenditures goes down. However it has been shown by econometric analysis that, while food consumption shows the expected pattern at any point of time in a country - that is, the relative expenditures of wealthy individuals and families are much less than those of the poorer - the pattern over time is not quite so distinctive. The decline in food expenditures through time is less rapid than might be expected from the cross-sectional data for a point of time (Deaton, 1975). It has been suggested by the econometricians that the rising importance of processing is an important reason for this slower decline in share over time.[9] Thus the decline of agriculture relative to national income has been much faster than that of food manufacturing - the value-added has been partially offsetting the decline in share of the raw materials.

The case for food manufacturing as a carrier industry however rests on much more than its mere size, significant as that may be. The old caricature of food processing as a rather sleepy industry has been changing rather sharply. Even today, food manufacturing is classified by innovation studies as a "supplier-dominated" industry, dependent on technological changes in more dynamic upstream industries for any progress of its own (Pavitt, 1984). In our view this image is no longer adequate.

On the side of the supply of technologies, the "supplier-dominated" perspective underestimates the role that empirical advances within the industry have long played. The major breakthroughs for the industry frequently arose out of needs generated within the sector itself, rather than being the chance application of ideas developed elsewhere for other purposes - examples include canning (at the beginning of the nineteenth century), pasteurization (in the middle of that century), and refrigeration (late in that century). In this sense, the "learning by doing" kind of technological change often received its initial stimulus from inside the industry, though further developed upstream. Secondly, "learning by using", in terms of modifying and advancing the equipment supplied from the mechanical engineering and other sectors, always remained a potent force. It is true

[9] Another view is that the location of processing has shifted from the household to the factory, e.g. through the kinds of additional or improved packaging noted below, and thus rather artificially distorted the data.

that the latter can be compatible with the "supplier-dominated" view of the industry, but recent advances go beyond that.

The major recent transformations of the industry can be summarised as follows. On the supply side, there has been a substantial increase in the application of scientific as opposed to empirical principles for systematic advance in the industry. More important still, the range of scientific disciplines and technologies recruited to assist in the advance of the industry has greatly widened in recent years. In the language of Schumpeter (1911), progress has come above all from *new combinations* - combinations of sciences, combinations of technologies, combinations of science and technology, and combinations of these with wider changes in materials, industrial organization, markets, etc., in ways that Schumpeter himself was at pains to stress.

Even these changes are, however, overshadowed by those on the demand side. In the last two decades or less, the balance of the industry has swung from being supply-driven to being demand-driven. It is changing consumer tastes and requirements that have become the major determinant of the industry's expansion. This has rarely, if ever, been the case before in regard to this industry, and it is the main reason for seeing it as prospectively a major carrier industry into the future. These changes on the demand side have fed rapidly back to changes on the supply side, for example in areas like food packaging. In this way, the model of technological change has become far less "supplier-dominated" than it ever was. In place of a kind of "linear" model of change dependent on upstream developments (which at best can be accepted only with reservations, as we have argued in Chapter 3 above), the relevant model of innovation is now much more like the interactive model with feedbacks as developed by Kline and Rosenberg (1986). It is difficult not to exaggerate the importance of this change.

5.2 Demand changes and product innovation

5.2.1 The context of demand

It is a widespread popular opinion that innovation in the food manufacturing industry mainly takes the form of new product development. Analysis has, on the contrary, shown that for much of the twentieth century this has not been the case. Instead, the leading characteristic has been one of great *stability* in the product range confronting consumers in a particular country. To explain this, we have to consider the oligopolistic structure that has typified the manufacturing branches of food and drink, briefly described in Chapter 2 above. The dominance of a smallish number of leading firms in many of the main product lines dates back in the case of at least some of the sub-sectors (like beer-brewing) to the early years of industrialization during the "First Kondratiev". Such firms were in the forefront of "the rise of the modern corporation" in the early twentieth century (Hannah, 1976), with much resort to takeovers and mergers.

The industry's desire for stability through reliance on brand-naming strongly discouraged product innovation, at least by the established oligopolistic firms. Once a brand name had entered consumer consciousness to the desired degree, the manufacturers sought to change it as little as possible (Horrocks, 1991; e.g. for the case of Cadbury's "Dairy Milk" chocolate, introduced in 1905). Innovation in such products was thus limited mainly to (a) improved processes for producing the same product, for which the firms were often dependent on their equipment suppliers, and (b) ingredient changes that preserved as much as possible of the product's sensory appeal but allowed production costs to be reduced (e.g. the replacement of cream with palm oil in ice cream by Unilever). Radically new products arrived occasionally, for example margarine, but these too tended to settle down to a cosy oligopoly dependent on brand image, after quite a short development phase.

With the assumed stability of final consumer tastes, major changes often arose from other sources of demand. Prominent among these was military demand, which emphasised first the need to offset the inherent perishability of most foods, and second the gains of easy portability. In response to Napoleon's famous dictum that "An army marches on its stomach", the Frenchman, Nicolas Appert, experimented with the heat treatment of foods during the Napoleonic Wars, finding that when combined with hermetic sealing it provided a satisfactory means of extending the "shelf life" of those foods; these advances led to canning, as the first really revolutionary change in food processing/packaging in the industrial era. Other areas in which military demand pioneered include instant coffee (the US forces responsible for developing much of the technology in World War II), the microwave oven (a spin-off from trying to use very short-wave radio for early radar), and plastic packaging (retort pouch systems from the 1940s).

As in a number of other industries, the impact of military demand on food processing and packaging has been waning in the later years of the twentieth century. The NASA space programme and similar mission-oriented public programmes had only a limited effect of changing the nature of food products. The civilian economy and traditional final consumers would now have to play the lead role in radical product change.

In the event, the role of final consumers over the past 15 or so years has radically altered innovation in the industry, to an extent unimaginable under the notion of the brand-loyal customers of the oligopolies. It is these who, *en masse*, have pushed the industry from being supply-driven to being to a much greater degree demand-driven. Their radically altered function has in turn been driven by broader socioeconomic and lifestyle changes, such that it seems reasonable to predict that these changes are quasi-permanent, though to date they have had very different degrees of impact in different countries. At the same time, they retain much conservatism about the sensory evaluation of food (they like their peas to be green, their yoghurt to be viscous, etc.), and industry's problem is getting the right blend of novelty and tradition.

There are some important examples of consumer tastes being influenced by the consumer durables which the rising incomes of consumers have allowed them to afford, especially as the costs of the appliances fell. Two of the most notable have been the diffusion across households of fridge-freezers and more recently of microwave ovens, both of which have had considerable impacts on the types of food consumed. Even these, however, also reflect underlying changes in lifestyle which have helped make their diffusion especially rapid in certain countries.

The major socioeconomic changes relevant to this issue have included:

a) Global competition between producers for market share, which has helped restructure tastes (Coca-Cola, MacDonald's, megabrand beers, etc.) and also restructure the older national oligopolies. Competition from new industrialized regions has undermined brand loyalties and provoked demand for novelty. The Japanese food manufacturing industry, for example, has been characterised for some decades by a high rate of product innovation, as has the North American industry in certain branches. These have both competed and collaborated with European producers.

b) Rising incomes and embourgeoisement of the social structure, which have increased demands not only for the consumer durables mentioned above but also for foodstuffs. As in other industries like automobiles, the rising incomes have encouraged levelling-up of tastes but also some diversification of tastes - a desire not just to "keep up with the Joneses" but to differentiate oneself from the Joneses. This differentiation of product demand has extended to processed and unprocessed foods in ways described below. It has paradoxically accompanied the "globalization" of taste patterns just referred to, with a great expansion of consumption of ethnically varied foods and meal structures, which the major retail chains now cater for.[10]

c) Rising employment of married woman in the workforce, albeit much of it on a part-time basis. Apart from boosting family incomes, this has helped encourage the interest in prepared or semi-prepared foods such as "ready meals", where demand has grown especially rapidly in the past decade. It has also altered shopping habits, in conjunction with a fall in average household size and with the household technologies noted above, towards once-weekly or similar behaviour in giant supermarkets (single people shopping spend one-third of their budgets on convenience foods). The retailers have been especially prominent in innovating in areas such as chilled ready meals, led by Marks & Spencer in the UK.

d) Increased pressure and stress in life, for adult males as well as females. This has encouraged an interest in rapid consumption as well as rapid preparation of foods. "Snacking" has also grown at unusually rapid rates in recent years, and along with it a burgeoning of snack foods. New York is often identified as the city where "grazing", i.e. eating sporadically in an unstructured way, first developed. Together with the preceding factors this has underlain a decline in regular sit-down family meals based on intensive preparation.

e) Changes in the age distribution of populations, especially the trend towards "greying" population profiles, have altered the composition of demand. There have been relative increases in demands for health foods, mostly purchased from

[10] Advanced packaging and microwave ovens simplify the preparation of exotic foods; see below.

specialist shops, and research into foods appropriate for specific physiological conditions, e.g. diabetics. Interest in vegetarianism has been growing, and by 1992 vegetarian foods constituted about 10% of frozen and chilled products (Bond, 1992), since when the proportion has risen. Recently there has been much concern with "functional foods", i.e. everyday food and drink products which add supplements that have direct purported physiological benefits, e.g. high fibre or protein-enriched.

f) Partly as an offshoot of this increased pace and stress of life, there has been increasing concern, especially in the wealthier countries, about personal health and deleterious eating behaviour for people in all age groups. There has thus been an enormous expansion in healthier foods, e.g. low-calorie, low-fat, low-cholesterol or low-sodium foods, as discussed further below. It has also required food manufacturing companies and government regulators to take much greater account of food safety, e.g. microbial contamination. However this has taken place in an environment in which consumers want much greater naturalness in their foods, which has been expressed most vehemently in the campaigns against chemical additives.

g) Thus environmental concerns have also strongly influenced the industry. In addition to the above, a major area of public concern relates to packaging, and especially the use of plastics such as PET.

It has been far from easy for the food manufacturing industry to comply with this range of change in tastes. For example, manufacturers feel caught between the Scylla of increasing the freshness and naturalness of foods by reducing additives and the Charybdis of increased risk of food contamination by micro-organisms. Especially difficult, and a major focus of research interest in the early 1990s, have been the organoleptic (i.e. sensory etc.) implications of "healthier" foods. Removing the fat or salt, or adding the fibre, etc., alters the taste, the aroma and the "mouthfeel" of the product. Manufacturers often feel obliged to compensate for these perceived losses, and add back ingredients which in a sense make the resulting product much more artificial than the original "unhealthy" item.

5.2.2 New Products

Many of these determinants and constraints surface in detailing the kinds of product-oriented innovation that have been conspicuous in the last few years.

a) More exotic foods. Spurred by the socioeconomic developments noted above, and by consequences such as greater international travel (exposing people to a much wider range of food styles), retailers in European and other countries have scoured the world for both raw and processed foods that would appeal to a more sophisticated consumer population. The common allusion to the breakdown of Communism in eastern Europe as the "kiwi-fruit revolution" is just one example of the permeation of new tastes and consumer aspirations. Brand names as well as product types have become internationalized in terms of both production and consumption, for example the widespread brewing of beer "under licence".[11] As implied above, the most striking change has, however, been towards ready meals that duplicate (as far as possible) ethnic dishes and meal patterns.

b) More prepared foods. For reasons given above, the amount of cooking and similar preparation in the home has been declining, and the purchase of ready meals off the shelf of supermarkets expanding. Analysis of new product introductions into UK supermarkets in the early 1990s has demonstrated that the fastest growth has been in frozen foods and especially in chilled foods and "ambient products" (sauces etc.) (Bond, 1992). These have required process changes and especially the maintenance of quality standards along lines discussed below. An offshoot has been the rapid increase in numbers of microwaveable foods - the microwave oven has limitations in regard to certain aspects of food preparation, such as adequate browning and crisping, and this has been countered by manufacturers in a variety of ways. Consumers have also been demanding foods that taste fresher, and this has been met in part by altering supply chains, for instance by in-supermarket baking of breads.

c) More casual foods. In conjunction with the lifestyle changes referred to above, there has been a rapid growth in demand for snack-type foods. In practice, there are large discrepancies from one country to the next in what are to be classified as "snacks" (White, 1994), but the overall trend towards more casual eating seems unmistakable. This has progressed fastest in the most industrialized countries, led by North America, north-west Europe and Japan. The frequent association of snacks with "junk food" has put pressure on producers to increase the nutritional value of snacks and to reduce the unhealthier characteristics to which they are particularly prone.

d) Healthier foods. The demand for low-calorie and similar preparations that reduced the intake of allegedly "bad" ingredients was promoted in the first instance by concerns about physical appearance and especially obesity. In southern European countries, this remains the most important element in taste shifts, but in the above-mentioned industrial regions the changes have been more extensive and "positive". These involve both the reduction of a wider range of "bad" constituents and the enhancement of allegedly "good" ones. Some of these changes are of long standing - for instance, decaffeinated coffee was first produced (by Hag) in Bremen in 1905, but consumption patterns have shifted more rapidly towards them in recent times.

It should be pointed out that scientific knowledge of what is good or bad is notoriously limited - for example, it has been shown that, while the relationship between blood-serum cholesterol and heart disease is evident enough, that between dietary cholesterol and

[11] Because of the (permitted) use of some local raw materials and standards, these local copies often differ from the product in the country of origin.

blood-serum cholesterol - or heart disease - is much less clear. Manufacturers in areas like sugar or butter of course have strong vested interests in asserting the healthiness of their products, and competing claims abound. Most consumers now accept the unhealthiness of tobacco, and this has led major manufacturers into quests for new markets (developing countries etc.) or diversifying out of tobacco (e.g. Philip Morris acquiring Jacobs Suchard). In regard to food products more narrowly, the main consumer concerns have been reducing intake of calories and fats, and replacing fats with complex carbohydrates (e.g. starch, fibre). Although there has been a marked shift in products such as breakfast cereals towards high-fibre and similar enriched items, there has been no great increase in per capita consumption. [12] A converse pattern seems to emerge for sugar, consumption of which has fallen little despite the undoubtedly growing use of sugar substitutes. Other items accepted as having health virtues have suffered from lengthy or awkward preparation, such as rice, which in turn has led manufacturers to developing rapid rehydration and "boil in the bag" varieties. Environmental concerns have also promoted some interest in materials preparation, as for sales of "organic" produce, but again growth has been rather slow, because of anxieties about safety and because of relatively high prices.

Although the shift to "functional" foods has been rather general across the advanced industrial countries, the products and health concerns have remained somewhat different. In Japan, for example, a major public concern is with consumption of oligosaccharides, which have been of little moment to European consumers (Hilliam, 1995). This has allowed scope for a certain amount of global co-operation in borrowing specific processes (such as the Japanese "surimi" process) and product types (e.g. oriental "puffed snacks" and crackers), without jeopardising product market shares. There has been some discussion suggesting that, by use of techniques to be elaborated upon below, functional foods may evolve into "designer foods", with more precise tailoring of a range of attributes as well as nutritional content.

It appears widely accepted, at least in Europe, that local markets remain quite strongly differentiated, and that US and other manufacturers aiming to penetrate the European market(s) have not fully comprehended the need for local product variation (Smith 1991). This point is developed more fully in Chapter 7 below.

5.2.3 New Materials (ingredients)

Similar factors to those mentioned for new products underpin the evolution of ingredients, and of course it is often the change in ingredients which brings about the change in product. For example, exotic meals require the addition of exotic spices and flavourings. Even here, however, the "exotic" ingredients can be applied to a wider range of foods and drinks. An example is provided by soft drinks, which have begun to incorporate a broad range of flavours, such as new herbals, new fruits, and "sports

[12] In the early 1990s p.c. consumption of fibre in breakfast cereals was still well below that recorded for the 1950s, partly because of a lower overall consumption of such foodstuffs.

drinks" (mostly based on dextrose). Even new tastes have been imported - the Japanese have promulgated the "umami" taste, which they claim differs from the four classic western tastes (sweet, sour, salty, and bitter), and which is associated with the presence of glutamates. Moreover, the shift to new forms of household processing like microwave ovens has had implications for the ingredients used - for example, it has been found that waxy maize starches perform much better in microwave ovens, as compared with the traditional starches that out-perform them in conventional ovens. Here we shall focus on two main types of ingredient change.

a) <u>The substitution of "natural" for "artificial" ingredients.</u> Consumer demands for natural rather than chemically based additives became intensified following German regulations of the late 1970s and subsequently EC regulations requiring the listing of such additives ("E-numbers"), not least because some of the additives like the colouring tartrazine (E-102) were earning a bad press for psychological or physical reactions, and some criticized as being potentially carcinogenic. The return to more natural ingredients involved higher costs in some cases, but this was not the only problem.

i) Additives used as emulsifiers, stabilisers, antioxidants, etc. figured conspicuously among the "E-numbers", and though many were probably relatively harmless, the publication of their presence alerted consumers and dissuaded manufacturers from using them. Oxidation of food is the main source of its perishability, and the more dubious chemical additives were in part replaceable by "beneficial" antioxidants like ascorbic acid (vitamin C), or proteins like glucose oxidase, or natural antioxidants like some tocopherols (including vitamin E). Gelling is increasingly being assisted by pectin, mostly obtained from apples, with the recent development of high as well as low methoxyl pectins, and recently of "instant" pectins.

ii) In regard to the more intrusive additives, influencing taste, colour, etc., the problems became more apparent. Many authentic flavours, e.g. strawberry, are harmed by even the slightest amount of processing, so substitutes have to be sought. Since additives produced from nature (plants, fungi, etc.) were deemed to be more acceptable, manufacturers thus searched for "nature-identical" additives. This included the investigation and analysis of a range of exotic natural products. A considerable difficulty is that there remain many differences in definitions of what are "nature-identical" additives, and one of the objectives of EU harmonization is to bring greater consistency into this area.

b) <u>The development of ingredients to compensate for the loss of organoleptic properties in "healthier" foods.</u> The reduction or virtual removal of elements like fats and sugar, as consumers increasingly demanded, was in itself relatively straightforward. What was problematic was to replace the contributions these elements made to the "mouthfeel" of the product. In some cases, like skimmed milk, no attempt was made to reproduce such "mouthfeel" (as compared with full-cream milk), and it was assumed that consumers would tolerate this. In most cases, however, this was not thought to be so, and a major proportion of product-oriented R&D in the industry as of recent times has gone into compensating for the loss of fats and sugars. Flavour “enhancers” like maltol and ethyl maltol are being used in the meantime for low-calorie foods, and hydrocolloids (food gums) to mimic the texture of edible fats.

i) The reduction of fats has been particularly problematic, in view of the range of attributes which fats add to the foods that naturally contain them. Carbohydrates like the maltodextrins replaced some of the properties of fats, as did emulsifiers, but efforts were made to bypass these too, either using process innovations like vacuum drying, or developing enzymic processes to obtain bulking agents. Protein alternatives are desirable for reasons just given, e.g. the use of isolated soy proteins in reduced fat and reduced cholesterol items, or whey protein concentrate from milk (and very recently whey protein texturisers).

ii) New substitutes for sugar were established in the chemical field. Saccharin had a long history as a sweetener, but the taste was deemed unsatisfactory in many uses. Cyclamates tasted better but on chemical grounds failed to win regulatory approval in many countries, including the USA and UK. Hence new “intense sweeteners” like aspartame found a large market in products like sugar-free soft drinks, but they too were challenged on chemical grounds, and in particular for their lack of bulk (glucose syrup often had to be added); moreover aspartame as a protein suffered some degradation through time. The sugar-based polyols (sugar alcohols), like sorbitol, mannitol and xylitol, many originally derived from natural sources, have been adopted instead in such items as no-sugar chewing gum. Enzymic processes for converting starches into sweeteners are being heavily researched, but products that replace all the functions of sugar simultaneously are not yet in sight.

Overall, we might classify the changes as involving: (i) a shift from chemical additives to the biopolymers (proteins and polysaccharides like starch); (ii) an associated upsurge of interest in enzymic processes for modification, discussed below in relation to biotechnology; (iii) the problems of meeting a diversity of functions (and particularly their synergistic interactions) supplied by food in its “natural” state, especially when the sources of those functions are wholly or partially removed; (iv) the role of legislation in limiting the changes that are permissible, though the regulatory structure for novel foods and ingredients remains rather chaotic.

5.2.4 Product Quality and Safety

A major shortcoming of removing additives and also the natural ingredients was of endangering the quality of the product. The main objective in product quality for manufacturers has been one of extending “shelf life”; an aim that as we saw above dates back to the development of canning two centuries ago, and indeed to the role of salt and spices in still earlier times. As manufacturers see it, consumers are wanting food to taste fresher and fresher, but with fewer and fewer of the constituents (preservatives etc.) that have traditionally offered such possibilities. But it was not just the ingredients that posed this dilemma - the same went for processes traditionally used to maintain food quality, like heating or freezing.

An important part of maintaining and (preferably) raising quality in food manufacturing had to do with the raw materials; for example the closer control of fruits and vegetables during growing, the reduction in animal stress prior to slaughter, and the development of soft wheats (rather than processing hard wheats) for biscuits. By and large these fall outside our concern, except in the sense that the whole food chain was in question. In countries like the UK, it is the large retailers (supermarket chains) that have taken control of the product chain, as purveyors of the fast-growing ready meals noted above. Marks & Spencer *et al.* exercise rigid (some would say ruthless) control over at least their domestic suppliers. To some degree, this change has been at the expense of closer links between manufacturers and growers (Raven *et al.*, 1995).

Within the food-manufacturing segment itself, advance has come from the whole range of possibilities, e.g. in beverages from a combination of changes in materials, processes and packaging, which have increased the stability of the product. These are dealt with individually elsewhere, but this is an appropriate point to focus upon instrumentation as a key field for monitoring product quality. Metrology - the science of measurement - has had to evolve in the context of rising awareness of the roles of chemistry, physics, biology, etc. in determining product quality performance. A major problem has been the difficulty of measuring many of the attributes of food quality that one would ideally wish to monitor. The rheological properties of foods (texture, viscosity, etc.) and especially the sensory attributes remain very awkward to measure by objective means.

An important and growing function has been to gauge the quality of the raw materials. Testing wheat quality was one of the first functions assigned to specialist R&D laboratories in the USA a century ago (Mowery and Rosenberg, 1989), and more recently the kinds of measures used have been augmented, e.g. using instruments to measure the extensibility of wheat in order to assess its hardness. Regulatory requirements have also been stepped up in regard to the quality of materials, e.g. EU regulations that require starches used in non-food applications to be 97% “food-grade” quality.

Application of instruments to food processing has raised even bigger problems. Testing in R&D laboratories, even if set up “in-house” within manufacturing firms, has customarily been time-consuming, skill-demanding, and only moderate in its accuracy. The normal procedure has been to take samples from a given product at the relevant processing stage, remove it to the lab, test it using “wet chemistry” methods by qualified scientists, then decide on its acceptability; by which time the offending item may long since have left the factory. Conversely, if (to meet regulatory standards or whatever) the results of the tests have to be awaited, there will be a long delay in production throughput. This is simply one way in which time is of the essence in modern food processing.

Time is not the only problem. The sample is not necessarily valid for the whole product from which it has been removed - in particular, the concern with most irregularly shaped foods is that information is required about what is taking place at the centre of the item (whether the centre has been adequately frozen, cooked, etc.), but this is difficult to discover without disfiguring the item in question. The despatch to the lab may also alter the sample's characteristics. Hence the main quest has been to develop methods of testing that are i) more reliable, and ii) applicable "on-line" and in real time (i.e. while continuous processes are actually taking place). The latter in turn requires procedures that can be used, and reliably, by relatively unskilled operatives on the production line; moreover it requires equipment that is not too cumbersome and is sturdy enough to be used on the factory floor. Many of the changes in instrumentation and quality assessment that have taken place in recent years fall into these categories; though there is still some way to go before on-line real-time evaluation becomes a reality in most branches of the industry. At the same time, it is becoming increasingly apparent that monitoring must be continuous; for example, the temperature of frozen or chilled products must be tracked the whole time ("full history") if product quality and safety is not to be risked, including more careful handling during retailing.

Advanced instrumentation itself has replaced some of the wet chemistry procedures, with all their shortcomings. Many have been adapted from first use in biomedical applications[13]: even more recent developments include X-ray fluorescence (e.g. to assess presence of salt or ash), ultrasoft X-rays (e.g. to detect meat contamination), and DNA assays based on monoclonal antibodies (for microbial detection, and increasingly for assessing texture, appearance etc. via the presence of biopolymers). These instruments are by no means cheap, though they are becoming economic for use in food-processing plants with sufficient scale (i.e. throughput levels). Their main advantages over wet chemistry are higher speed, increasing user-friendliness (ability to be used by semi-skilled operatives), lack of environmental risk, and accuracy; though these problems have by no means yet been fully solved. Interpreting the spectra from, say, Near-Infrared Spectroscopy (NIR) remains quite an art, despite the growing availability of computer processing of the output; and the now-popular combination of chromatography and spectroscopy for analysis, apart from being somewhat expensive in equipment, still requires some sample preparation (via centrifuges, filters, etc.). In addition, it is being realised that scientific predictions are of little use, because of generally being carried out under "optimal" conditions - hence mathematical modelling is trying to incorporate a wider and wider range of variables of the kinds actually encountered under production conditions.

As implied above, many of the most critical characteristics of food still by and large lie beyond the capability of instruments; above all the organoleptic properties, for which panels of alleged experts remain the overwhelmingly dominant method of assessment. Attempts are under way to supplement these rather subjective procedures, e.g.

[13] Examples include electrophoresis for protein analysis, Nuclear Magnetic Resonance (NMR) for determining the quantities of liquid present etc., Near-Infrared Spectroscopy (NIR) and other types of vibrational spectroscopy for measuring moisture and also protein etc. (and alcoholic content of wine in France), plasma emission spectrometry for detecting minerals.

physiological monitoring of the panellists themselves (electromyography), or the use of gas sensors as an "electronic nose", or optoelectronic means of assessing colour, or machine-vision methods (using lasers etc.) for sorting and for analysing high-speed motion; but most of these are understandably in their infancy. Greater rigour in panel assessment has been sought, for example through "quantitative descriptive analysis" (QDA) or the application of expert systems etc. Here too it is being found that analysis has to be continuous rather than one-off or intermittent, and of course this is very labour-intensive. Equally it has been shown that there is a large amount of discrepancy in judgements between different countries, which no doubt include objective discrepancies in what is being looked for as well as subjective discrepancies in panel quality. EU harmonization programmes have been initiated in such areas, especially the FLAIR (Food-Linked Agro-Industrial Research) programme which ran from 1989 to 1993, and a European Sensory Network was established in 1989 (indeed the latter helped demonstrate the cross-country differences just mentioned - an issue we shall come back to later). Additionally, there have been attempts to award European accreditation to laboratories meeting acceptable standards in their testing, as it is granted that in practice measurements vary quite widely between different labs.

Supranational and national regulatory bodies also exist to oversee any attempts to pass poor-quality food and drink off as being of good quality. Since time immemorial, the industry generally has tempted its producers and distributors into adulteration (e.g. Hobsbawm, 1957). The original Food and Drugs Acts in the UK (1875) were passed to try to counter fraudulent practices of such kind. The industry - like many others - is often to be found replying that its members stand too much to lose from cheating, especially the large oligopolistic concerns, and has tried self-regulation by detailing "Good Manufacturing Practice" (GMP). It is however obvious from the much-publicized court cases that the practice has far from disappeared, though it may well be diminishing. Wines and fruit juices (a high proportion of the latter advertised as 100% pure but in fact variously containing extra water, sugar, "extenders" like pulpwash, colours, acids, etc.) have figured prominently here. New technologies give opportunists a broader range of potential tricks of the trade, but equally they give the regulators greater powers of detection. It has been argued that the situation is best seen as one of an on-going evolutionary race between adulterators and regulators (Hall, 1992).

Quality assurance standards like ISO 9000, BS 5750 and EN 29000 have been of some use in focusing attention upon quality issues (also EN 45000 for good laboratory practice), but have been nowhere near adequate to meet the main concerns directed by the public against the industry. This is most evident in safety standards, and especially the dangers of microbial or other contamination of foodstuffs. To meet these - and indeed the wider range of issues - a major objective for the 1990s has been to identify and respond to specific aspects of the production process that could possibly create hazards, and these are known as Hazard Analysis Critical Control Points (HACCP). There is general agreement that imposition of such criteria calls into question much more of the food manufacturing process than do the orthodox quality control standards, for example insisting upon assessing the slowest heating or cooling points. The EU has programmes to elucidate HACCP standards, but it is quite apparent that just their identification, much less their harmonization, is extremely onerous. Nevertheless, the industry has to think in terms of gearing its processes and products to HACCP within the foreseeable future. This will necessarily involve more accurate and much faster on-line methods and instruments.

As with quality testing more generally, the objective in safety assessment is to establish real-time evaluation, and combined with production control (e.g. on continuous processes). Traditional microbiological tests to detect e.g. listeria or salmonella are notoriously slow, taking up to several weeks to produce results, because of the sequence of stages of sample pre-enrichment, enrichment and plating out that have to be undertaken before biochemical testing. The accuracy of the results seems acceptable; the problem is that the procedures are time-consuming, costly, and sample-specific. Developments in instrumentation have cut the time required to a number of days (less than one week), but the time lapse is still far too long for practical effectiveness. Currently much favoured are identification methods emanating from genetic engineering, like DNA "fingerprinting" or nucleic acid probes; progress is rapid but many problems remain. Of particular interest has been the utilization of the "Polymerase Chain Reaction" (PCR) for DNA enrichment, as developed in the USA jointly by Cetus (from the biotechnology side) and Perkin-Elmer (from the instruments side), which drastically reduces the enrichment stage. Equivalent if less dramatic advances have been taking place in identifying non-microbiological contaminations e.g. by heavy metals or by foreign bodies like glass splinters (including dealing with outbreaks of tampering).

These advances in techniques and accompanying regulatory changes were partly a response to safety scares in the late 1980s. The suggested solutions ranged from the simple to the complex. Much could be done by improving hygiene criteria for the equipment - designing the machinery for hygienic operation as well as making maintenance (cleaning) more straightforward. At the other extreme, evidently the adequacy of food science and technology was much less than the industry and others believed. The BSE scares have made this all too plain, along with the costs the industry will bear if it transgresses. A conclusion that many drew is that approaches to food quality and safety had to become much more multidisciplinary, not only because of the complexity of the food products but also because of the complexity of the problems they raised.

5.3 Supply changes and process innovation

5.3.1 Scientific advance

This multifaceted approach to the problems encountered by the food industry has been revealed in its recruitment of a much more diversified body of sciences. The industry had a long tradition of solving its problems - or at least partially solving them - by empirical means, with the science (if any) following after, e.g. pasteurization-microbiology, refrigeration-cryology. Attempts were indeed made from a relatively early stage to increase the scientific content of food production, but apart from isolated areas such as those just referred to, these by and large earned a poor reputation. Food science (or "domestic science") was seen as a substitute for the "hard" sciences like physics for women to study; with the implications that it would not be over-taxing of their supposedly tenderer intellects, and that it would prepare them for married life in the home. Many secondary schools in the UK set up such courses, and at least one university college (King's College for Women) was founded for these purposes (Dyhouse, 1981, pp 167/9). The subject was heavily criticized from its inception both for its content and for its motives, but to this day science in the food area carries certain connotations of these kinds, which has probably hindered its progress. Most now however accept that, far from being relatively "soft" and easy, the science required for such applications is in fact for the most part very demanding, not least because of the multidisciplinary standpoints involved. The more that science is applied, the more it becomes evident just how little science has so far achieved.

a) Mathematics. Predictive modelling in areas like microbiological and other contamination has been going on for over 60 years, e.g. predicting the lethality of bacteria, or the impact of radioactive fallout. The poor performance of these models in practice, as shown up in outbreaks of food poisoning, or in the gross under-estimate of some of the consequences of Chernobyl, have (as mentioned above) induced the development of models encompassing a much wider range of variables, as empirical analysis and the findings of other sciences show them to play their part. These much more complex models require not only more demanding analysis in the mathematics (e.g. computational fluid dynamics), but resort to simulation and the adoption of multivariate statistical procedures.

b) Computer science. For real-time analysis, the interpretation of data such as the Fourier transforms used in NIR spectroscopy etc. requires very fast computing power. Naturally, the availability of high-speed workstations at comparatively low cost has greatly facilitated the adoption of such instrumentation in the past decade or so, and the instruments and computers can readily be networked. Problems of the user interface have also been much diminished. Databases are currently under development, though much needs to be done to network these. The biggest difficulty nowadays in most cases - as in many other areas of computer application - lies in the software. Gradually the software needed to maintain quality standards along the food chain is emerging, but the "bottleneck" is a constrictive one. User software has been identified as the greatest single cost in developing process control systems (Womersley, 1991). Expert systems have been proposed, and a number developed for factory-level use. The main focus now is however upon the rival approach of neural networks (Wallin, 1995); the reasons being that practical data arising out of food processing are inherently somewhat "fuzzy", and that systems which allow the programmes to "learn" have enormous advantages where even the underlying principles remain rather obscure.

c) Physics. The increasing use of advanced instruments, and the growing awareness of the complexity of the relevant physical processes and modifications, have promoted interest in more formal development of the physics of food manufacturing. The basic processes like heating and cooling are greatly dependent on such understanding and on advancing it. Optics and sonics are both being adopted in highly imaginative ways to deal with some of the industry's more intractable problems. New areas like irradiation of food to destroy bacteria have been developed, but their use remains costly and rather controversial.

d) Chemistry. Chemists have traditionally dominated scientific recruitment into the food-processing industries. If anything their importance rose as recently as the 1970s, when consumer pressure for reliable food first began to be exerted. As implied above, this pressure moved away from chemicals during the 1980s, and with that went some loss of faith in what chemists could do (coupled with the growing need for filling other scientific gaps). However, important chemical advances continue to arise, for instance there remain many adherents to chemical processes for modifying proteins (relying on safe reagents). Moreover the chemical industry and especially the pharmaceutical industry appears to be the model of organization that many in the food industry implicitly aspire to. Many of the instruments and techniques it employs were "borrowed" from earlier use in these industries.

e) Biotechnology. The shift away from wet chemistry has mostly been to the gain of biological approaches. Food and drink was of course the major area of application of biological technologies from ancient history (baking, brewing, etc.). But as in areas like pharmaceuticals, though even more powerfully, it is the potential of latest-generation biotechnologies that have attracted most research. Enzymic methods are being sought to replace chemical additives of virtually all kinds, and this is an industry which habitually uses many of them. The first enzyme products from genetically engineered organisms entered the market in 1989/90, based on work done at MIT etc. The implication is that biological approaches are likely to be much safer, although current regulatory standards in some countries (those that adopt the "positive list" approach of what they will approve, rather than the "negative list" one of what they disapprove of) often run counter to this presumption. Protein engineering, which has been at the leading edge of recent applications of genetic engineering, has thus proved especially attractive a prospect e.g. in replacing purification techniques, though much remains to be understood of the basic biotechnology itself.

The use of proteins in food goes well beyond their nutritional value, for example to incorporate their roles in thickening, water- and fat-binding, gelation, foaming, emulsification, colouring and taste.[14] The consumer take-up of bio-engineered foods like mycoprotein has however been disappointing to some. For the time being, it looks as though the main uses will be for ingredients and their modification (including improved starter cultures), and for product quality and safety assessment (using the DNA assays as outlined above).[15] Some proteins

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[14] Greater specificity of enzyme use in recent applications include lactase in milk, alpha-amylase in bread, lipases in fats and oils, phospholipases for emulsifiers, and widespread use of proteinases e.g. for cheese ripening, soup flavouring and meat tenderising (Law, 1990).

[15] In the past, the main use of enzymes has been for degradation (hydrolysis, e.g. hydrolysing proteins into peptides), but a much wider range of applications now seems attainable, especially in low-water environments (e.g. for producing emulsifiers or conducting biotransformations) where enzymic methods consume much less energy etc. than chemical ones, and can produce

> themselves can be used for rapid microbiological diagnostics (e.g. lectins). The shift to "healthier" foods described previously is a major stimulus to research and development in this area: it is biotechnology that is being mostly considered to resolve the inherent conflict between the naturalness and the maintenance of freshness of foods. The particular role of biotechnology is further isolated in other sections of this Report, e.g. in the discussion of patenting in Section 6.3.

Other areas of current scientific focus are likely to prove significant for the food industry, like optoelectronics. In the meantime, we can however expect that such expertise will mainly be sought from outside the industry. Within the sector, the issue is often seen as one of choosing which scientific approach will be adopted for a particular problem, where the choice is either/or. For example, the modification of milk to produce "healthier" butter can be undertaken by physical means, by chemical means, by biotechnological means (now much researched), or by dietary means (changing what is fed to the cows - this seems the simplest and arguably the best). In the longer term, the overriding concern is likely to be with bringing together the results of such heterogeneous scientific advance into developments that are of concern in production. This highlights the importance of the "transfer sciences", to which recent work in innovation studies has called special attention (OECD, 1992). It also highlights the need for improved networks of communication, as the complexity of demands becomes more and more apparent. The past record in terms of, for example, links between nutritionists and toxicologists, has been distressingly poor.

5.3.2 Processes

The processes employed in manufacturing food and drink thus aim to coalesce this multiplicity of scientific advance with the rapidly growing importance and change in final demand demonstrated above. Both heating and cooling have been profoundly transformed by these new requirements.

Some of these changes have been drawn directly from the demand-side technologies themselves; for example there is growing use of microwave heating in industry-scale operations, including its use for pasteurization (at moderate levels of heat) and tempering (raising the temperature of frozen food without thawing). The familiar domestic advantage of microwaving for rapid treatment is essentially duplicated for industrial purposes, though this requires greater care in the handling of the process in view of its being very rapid. Industrial-use microwaving also has to take particular care about the lack of penetration depth of microwaves into food substances.

a) Cooking

On the side of cooking, the main objectives have been to shorten the process and increase its flexibility (adaptability to different products). The industry has long opted for heat exchangers as the most cost-effective and rapid means of heating in the context of

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more targeted products.

continuous processing, and developments continue regularly in regard to all the major types of heat exchanger (plate, tubular, scraped-surface, etc.), each of which has distinctive advantages or disadvantages for particular types of product. High-temperature short-time (HTST) processing has been sought, in the wake of success in extending shelf-life with UHT (ultra high temperature) processes and products, like long-life milk.[16] As with microwaves, process control has to be intensified, to get the right balance between too short a time (which would fail to destroy bacteria) and too long a time (which would harm the product quality), and equivalently the right balance of temperature. Because most foods are non-Newtonian in their flow properties, the knowledge of rheological behaviour under conditions of, say, UHT processing is still very limited.

The changes in demands for cereals, snacks, etc. have helped prompt a radical change in method from rotary cookers to extruders. Extrusion cooking, originally using a single screw within a barrel, raises the shear imparted by the equipment, with substantial effects on cooking time and textural quality. Extrusion cooking can be conducted much faster than rotary steam pressure ovens (pass-through time is typically 30-90 seconds), and continuous rather than batch processing is much facilitated. The extruder barrel can conduct a range of processes such as grinding, mixing, compressing, heating, cooking, sterilizing, deodorizing, shaping, texturizing, drying and cutting. Subsequent modifications such as extending barrel length have increased its range of advantages; furthermore the disadvantage of shorter shelf-life of many early products is being overcome by use of different ingredients. The most important development within this field has, however, been the shift from single-screw to twin-screw extruders, which not only double the capacity in unit time, but allow straightforward co-extrusion, for items that require combinations of major ingredients - as is true of many of the new product types alluded to above.[17] Thus extrusion cooking gives rise to economies of scale, though in the recent sense of greater throughput rather than greater size of operation (von Tunzelmann, 1995b) - extrusion cooking generally economizes on space instead of taking up more of it. This allows its combination with economies of scope, in the sense of flexibility in regard to the items being cooked - extruders can be converted extremely rapidly from cooking, say, filled, coated and dual-texture breakfast cereals to snacks (Davies, 1990) - and in the sense also of combining substances for co-extrusion (Jones, 1990, 1991). Very specific tailoring of the cooking process to the desired product can be undertaken, allowing gains in terms of texture, flavour, etc.; following which the extruders can quickly be re-programmed for quite different products. The issue arises not just in cooking but in other phases of the production process, e.g. the use of high-speed mixing (multiprocessors have been developed for complex products), or accelerated drying (spray drying, fluidized bed systems, or freeze drying). The industry has been criticized for devoting too much attention to high speed and not enough to high flexibility (e.g. Kaye, 1992), and such equipment can help effect a better compromise; though this

[16] There has also been recent interest in ohmic heating, with the production of equipment by firms like APV.

[17] For instance, sausages are increasingly being produced by co-extrusion of the filling ("dough") and the casing, using collagen paste.

may also require changes in the product lines themselves, like greater modularity (e.g. Greeves, 1990; also ECE, 1991, pp 59/60, for packaging machinery).

b) Freezing

On the side of freezing, the basic techniques of contact freezing have been understood since Birdseye's work in 1928. The basic objectives parallel those for heating - economies of time and space, reliability and (less problematic here) flexibility. The shift in demand from frozen to chilled products has increased awareness of the need for accurate information on i) the extent of penetration of chilling or freezing into the food product (typically rather irregularly shaped) and ii) monitoring temperature through the whole process up to final sale. A considerable difficulty is that freezing processes are inherently nonlinear. It was established at a fairly early stage that rapid freezing generally did much less harm to the product than slow freezing (blast freezing); although it later emerged that there are some exceptions and the issue remains much debated, e.g. for meats. Additives (cryoprotectants) may have to be employed to slow down some of the more disruptive aspects of the process. Very rapid freezing techniques (cryogenics), using liquid nitrogen, have been employed for certain purposes, particularly for "crust freezing" (to maintain surface colour), and recently the range of uses has greatly expanded (Tomlins, 1995). Freezing systems have customarily been developed on technological criteria, especially to optimize the performance of the evaporator, and only recently has there been a switch of emphasis to optimizing for the product itself (Bailey, 1993).

c) Production integration

Aside from the processes employed at these key stages, there are important issues that arise in connection with the overall integration of production. One concerns extraction and separation. Supercritical gases/fluids, generally carbon dioxide, are now becoming more widely used for extracting certain ingredients, in place of traditional liquid solvent extraction and distillation, e.g. for seed oils, fats, spices, drugs and medicinal herbs; though the capital costs remain high. It is becoming increasingly common to separate as much as possible at the beginning of the process, and re-combine the elements as late as possible before final despatch. This applies not just to the obvious constituents, but to aromas etc., which as noted above are often highly sensitive to any processing. The "spinning cone" method, as now used in low-alcohol wines for example, adopts this approach. In beer-brewing, many large companies have developed a bland "base beer" for process efficiency, to which elements like bitterness, hop aroma, colour and foam are added late in processing.

Flow through the whole process is central to continuity and to automation. While beverages are generally straightforward to handle, certain types of particulate foods are often difficult, though their flowability has to be maintained. Distributed PLCs (programmable logic controllers), replacing relays, were employed in the 1970s and '80s for such purposes, but their power was not adequate to meet many needs. They have been overtaken by modern microprocessors and computerization. The adoption of IT in food processing has however fallen below expectations, not least because so many operations remain "art" rather than "science" ("fingertip feeling"). The stumbling block in many areas of automation has been the instrumentation for on-line quality control, and especially the lack of adequate sensors to assess such "difficult" products. This is slowly being met, but the requirements are arguably rising almost as rapidly (e.g. the sensors crucially required for HTST processing). As noted above, equipment originally developed for quite different purposes is being imaginatively applied to food processing needs, for instance both low-intensity and high-intensity ultrasonics (though here too sensors remain a problem), and machine-vision systems. There is growing use of vacuum processing for cooking, cooling, thawing etc., to raise speeds and reduce damage. [18] The Japanese however lead in application of high pressures, e.g. for preservation (Earnshaw, 1992; Galazka and Ledward, 1995). The automation of transfer functions using AGVs (automatic guided vehicles, e.g. with laser tracking) or similar is becoming popular.

Essentially, it can be said that technology in the industry is being driven by systems that cope with variety (Poley, 1993). As with the scientific developments, the technologies increasingly need to be integrated with one another, especially as the production systems become more strongly integrated in the interests of altering consumer demand. Reflecting the overall shift of emphasis in the industry from supply to demand factors, efforts are under way to shift the orientation of automation from the machinery to the product.

5.3.3 Packaging

In the early 1970s, “tin” cans and glass bottles and jars remained the standard forms of packaging for food and drink. Since those days, when packaging was largely an afterthought, the packaging processes and products have been radically transformed. These changes were part and parcel of the changes in products and processes higher up the food chain, as described above, and indeed they often had to be developed in conjunction with one another.

Most significant in this respect were the forms of packaging adopted for the chilled foods and ready meals. These had to allow for the heterogeneity of such products (trays with several compartments, sachets, etc.), and also for the conditions under which they would be prepared in the home. Plastics and seals that could be heated in ovens without themselves deforming or adversely affecting the food they contained, and subsequently those usable with microwave ovens, became the subject of considerable research. Crystallized PET (polyethylene terephthalate) has been developed for the trays (ordinary PET cannot withstand the temperatures encountered in an oven). For microwaving there was the additional problem of browning or crisping the cooked food in the short time it was in the oven, as mentioned before. Recent solutions have focused on the properties of “smart” materials, in this case susceptor packaging that would itself react to the heat treatment and thereby improve the nature of the cooked product. While progress here has been rather impressive, there remain doubts about susceptor packages, including the possibility of toxic effects.

More generally, progress had two main objectives: i) developing aseptic packaging, to improve safety standards; ii) developing controlled or modified atmosphere packaging

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[18] An extreme example is the Italian cake, Panetonni, which takes about 24 hours to cool in air and 4 minutes under vacuum.

(CAP and MAP), to offset declining quality during extended shelf-life. Aseptic packaging, which involves separate sterilization of product and packaging, attracted considerable interest from the industry; but it has been claimed that consumers have shown less interest, and that it has failed to repay the investments in it (Kaye, 1992). On the other hand, for reasons already given, the industry at large may lose from any lack of commitment to high safety standards. CA and especially MA packaging, on the other hand, appear to have been quite successful. These cover a range of situations. CA packaging restricts the changes that can take place within the container. The main problem is oxidation, the most common source of food perishability. Although it is technically possible to block out all the oxygen (by vacuum packaging and perfect sealing), it is usually inadvisable to do so, because products like meat respire and change in other ways while on the supermarket shelf. CA packaging therefore aims to allow in just enough oxygen (etc.) to offset these changes. MA packaging can be regarded as a form of CA, in which conditions in the package are initially altered to suit the character of the product and its perishability - a typical solution is a mixture of carbon dioxide to inhibit microbial action, nitrogen to limit oxidation, and sometimes oxygen to retain colour e.g. of red meat. MAP can be combined with “active” packaging in which additives are included in the packaging film (laminated PET susceptors) or within the container to enhance freshness. As noted, various forms of these are now widely used in chilled ready meals etc., although it has been claimed that their use for storage of certain vegetables etc. is unnecessary and costly (Saráy, 1994).

These developments in turn rest on advances in i) materials used for the seals, ii) methods of sealing and filling. The materials involved are mostly laminates containing two to four layers of suitable polymers (polypropylene etc.) or aluminium, each designed to provide a high barrier against the outer or inner environment (gas, water, etc.), and surface coatings are commonly applied as well. Naturally the most suitable polymers etc. vary according to the nature of the product, and R&D work here is often of a high level of sophistication. The problems do not however end with obtaining and producing suitable materials. The forming (of the material shapes), filling and sealing are usually done in single complex machines, known as form-fill-seal machines (FFS), which require very high precision and advanced microprocessor controls. Filling is much more precise than for cans or jars because the seal area must not be spattered with the product. Sealing, usually with adhesives, can be variously hot or cold; the latter being much faster though raising other difficulties. The packaging as well as the products have shifted from being supply-driven (reduced costs, faster speeds, etc.) to being more market-driven, with attempts to catch the consumer’s eye in one way or another, so that advances have been continuous. Closures have attracted particular attention - tear-strips, tear-strings, corner separations, etc.

For liquids, there have been other changes running concurrently with these in the past two decades or so. The two-piece “tin” (i.e. tinplate) can has partly given way to other types of metal, particularly aluminium. The glass bottle has given way to both cartons (Tetra-Pak etc.) and plastics, particularly PET. These carried advantages in terms of lighter weight, less fragility (than glass), storage convenience (rectangular shapes etc.) and permitted the development of user-friendly closures (ring-pulls, twist-off plastics, reclosable carton lids, etc.).[19]

On the other hand, there has been rising public resistance to excessive packaging, affecting both food and drinks containers. There has been concern about the environmental effects of production processes for packaging such as PET (petrochemicals). There have also been demands both for more recyclable materials (and facilities) and for less wasteful packaging. Regulatory standards will undoubtedly bear more heavily on manufacturers in these terms, with the EU programme designed to set targets for reduction to be achieved by 2003 (15% reduction in packaging and 60% increase in recycling). Even more problematic are regulations concerning "migration" between package and product. Manufacturers have long been concerned about the "scalping" of flavours by the packaging; regulators tend to be more concerned with the migration of substances from the packaging (including printing inks) into the product, with possibly harmful effects on the consumer. The closer the packaging to avoid oxidation, the more likely such migration must be. Some of the newer materials are at a disadvantage in this respect, for example there is more migration from PET bottles than from glass. The EU programme for harmonization of migration standards is accordingly being developed over the years 1993 to 1997.

Packaging is thus a good illustration of four of the main themes pervading this survey of recent innovation in the food manufacturing industry: i) the need for adequate instrumentation for monitoring quality and safety (infrared spectroscopy and gas chromatography are now used for analysing packaging); ii) the need for conjoint development of product and package; iii) the rising importance of consumer "voice"; and iv) the rising importance of regulatory standards and their harmonization.

5.4 Summary

We can thus summarise the patterns of recent innovation according to such headings. The most striking observation is the radical nature of both product and process innovation in the industry over the past twenty years or so. While this has frequently been pointed out in regard to the "high-tech" industries, for example in the long-wave literature, it has much less often been noted for pervading a range of industries usually regarded as being rather "low-tech". Of course there is a high degree of dependence on those developments in high-tech areas, like information technology, biotechnology and advanced materials as demonstrated above; but there is much more to pervasiveness than the simple "supplier-dominated" view of such industries would suggest. In particular, we may draw attention to the great variety of technological impulses which "suppliers" are being called on to deliver to these "users" - the range of scientific disciplines and technological fields -

[19] Recent developments include such items as bag-in-the-box, which incorporates food as well as drink packaging technology (automatic filling, coextrusions, etc.), and usually a foldable tap closure.

and still more to the complexity of integrating these through indigenous efforts within the "user" industry such as food processing.

These supply-side impetuses are if anything being overshadowed by changes on the demand side, exerted through consumer behaviour (including the effects of "globalization" of tastes and products), through public opinion, and through intensifying regulatory standards (in regard to health, safety, environment, etc.), which are of course partly by way of response to public opinion. The shift of emphasis from technology to product is altering the structure of process change in the sense of how automation is developed, and also altering the nature of competition and collaboration in the industry. The interactions between the supply-side elements (different technologies etc.) and especially between the demand side and the supply side are likely to prove the key determinant of national and supranational success in innovation in the industry.

6. Features of innovation at the firm level

The focus in this Chapter is upon three sub-themes, all of them studied at the firm level. First leader and laggard firms within the industry are characterised. Subsequently the role of firm strategies is investigated. Finally the relationship between innovation and profitability is explored in much greater detail. The first thing to clarify in a study of success factors is to define what is meant by "success". Two criteria are employed in this study. As the study is on innovation, the share of innovative products in total turnover is taken as one indicator of success, and the growth in turnover from 1990 to 1992 is the other one. It could, of course, be discussed whether other indicators - both economic and non-economic - should be chosen. Ideally the success indicator should be compared to the objectives of the firm. What is an indicator of success for one firm is not necessarily a success criterion for another. It is however likely that firms would regard growth in turnover as being an indicator of success. It should first be mentioned that the share of new products in sales does not capture improvements in process development. It could also be questioned whether the two indicators are interrelated or perhaps in some cases contradictory. A growth in turnover of a firm may actually reduce the share of innovative products in its total sales if the growth in sales has taken place in older products. With regard to the second indicator, the time period that it is possible to investigate could be said to be rather short for assessing success. It could also be argued that different countries experienced different levels of overall macroeconomic behaviour during the period 1990-92. This will obviously have an impact on turnover growth. These reservations could be expanded. For now they serve as illustrations that the choice of criteria for "success" is far from trivial. The criteria chosen here are respectively related to innovation activity and purely economic, and they are both in the CIS database for most countries. However a few countries, i.e. Norway, Greece, Spain, and Portugal, do not list 1990 turnover. This prevents us from using the growth of turnover as a success criterion. In these cases the share of innovative products in turnover is used. In conclusion it can be said that the success criteria chosen are imperfect, but when using the CIS data they are the best that we have got.

Leaders and laggards have been calculated separately for each country: the best performing third of firms being the leaders and the worst third being the laggards. The remaining third is not shown in the tables, which explains why the total may differ from the range between leaders and laggards. For both measures of success - especially the second one - many reservations need to be made. This is however the best approximation offered by the CIS microaggregated dataset.

When exploring the relationship between innovation and profitability we need data on economic performance over time at a firm level. The CIS data are not adequate for this purpose. Using other kinds of data for innovativeness we compensate for this inadequacy in that Section (6.3) by focusing on firm-level data from their accounts.

6.1 Identification of leaders and laggards6.1. Identification of leads and laggards

The purpose of this section is to investigate whether leaders and laggards within the industry share common characteristics. This investigation is undertaken for a number of possible dimensions, as shown in Table 6.1.1 overleaf. These dimensions will be commented upon in turn before summarising what are the characteristics of leaders and laggards.

a)Growth in turnover

The table shows rather large differences between leaders and laggards in turnover growth in each country. In most cases laggards experience on the average a negative growth (decline) in turnover of around 15% whereas leaders grow at a rate of 45-60% in the same period. Even within the groups there are substantial differences. Coefficients of variation range from 49 for leaders to -204 for laggards. Coefficients of variation for the totals vary between 202 and 270. It should be expected that substantial differences between leaders and laggards would emerge because the two groups are defined by ranking that variable. The countries share common characteristics in terms of total growth in turnover, averaged across them. For the countries where a growth rate can be computed, it stands out that the firms in the different countries have a total growth of 17% +/- 2%. It should be expected that growth rates are relatively similar across the countries, partly because of increasing internationalization of the markets, and partly because of the relatively stable demand in times of upswings and downswings of the economy, as previously explained in Chapter 2. This expectation is largely fulfilled. Across countries leaders show approximately the same growth rates, except for Greece, and the same goes for laggards (although laggards in the Netherlands apparently do rather better).

b) Export shares

Results from export shares are difficult to relate to the performance criteria. There are cases of both leaders and laggards having the largest share, and only the Belgian case shows a clear, positive difference between the share of leaders and that of laggards. On the contrary, Norwegian laggards have export shares substantially above those of leaders. Between countries we see large differences in the absolute level of shares. These differences largely reflect the size of the home market. Thus Spain, Italy and Germany have small export shares whereas Denmark, Belgium, Ireland and the Netherlands have large export shares. Small export shares in Portugal and Greece are more difficult to explain. At first sight they may be explained by the geographically isolated position of these countries and the specialization of producers which is influenced by specific local tastes. However, Portuguese food and beverages producers, especially, are rather export-oriented. It may be surmised that the adverse macroeconomic conditions of this period, which probably affected all European trade patterns, partly account for the seemingly poorer performance of large exporters in these years.

c)Turnover per employee

The turnover per employee is an inaccurate proxy for productivity in firms. It may nevertheless provide some indication for a hypothesis that leaders would tend to have higher turnover per full-time employee than laggards. The results however do not confirm this

Table 6.1.1: Characteristics of leaders and laggards

Countries	Ranking	Growth in turnover, %	Export share %	Turnover per employee (KECU)	Innovation cost intensity	Share of unchange d products	R&D intensity
Belgium	Total	19	36	306	**	62	12
	Leaders	60	45	431	**	51	9
	Laggards	-16	32	258	**	71	16
Denmark	Total	17	44	181	13	62	22
	Leaders	52	42	206	16	64	19
	Laggards	-16	42	137	11	51	13
Germany	Total	n.a.	11#	169	66	57	8.6*
	Leaders	n.a.	7#	116	142	14	22.7*
	Laggards	n.a.	11 #	213	23	91	2.4 *
Greece	Total	-2	12&	129	2.4#	n.a.	8
	Leaders	14	20*&	157	4.0*#	n.a.	1.3*
	Laggards	-23	6*&	82	1.2*#	n.a.	0.8*
Ireland	Total	15	33	258	28	74	14
	Leaders	44	38	278	27	66	22
	Laggards	-11	34	206	16	83	11
Italy	Total	16	10	438	26	81	22
	Leaders	54	10	327	20	79	2.1*
	Laggards	-15	10	713*	26	81	19
Netherlands	Total	16	35	323	21	68	2.3 §
	Leaders	45	36	311	45	69	5.2§
	Laggards	-8	31	338	11	69	1.0§
Norway	Total	n.a.	23	284	18	60	19
	Leaders	n.a.	14	338	22	35	3.2*
	Laggards	n.a.	34	257	21	91	16
Portugal	Total	n.a.	16&	305	0.9&	64	**
	Leaders	n.a.	10&	105	0.9*&	26	**
	Laggards	n.a.	20&	636*	1.5*&	97	**
Spain	Total	n.a.	8	183	30	61	1.0&
	Leaders	n.a.	11	186	44	23	1.4 &
	Laggards	n.a.	6	158	22	92	0.7*&

Notes: Calculated from CIS data.
#Only partly comparable
&Not comparable
§Results for R&D in the Netherlands tend to be overestimated because of differences in formulation of the questionnaire
*Less reliable data because of low number of observations or outliers
**Non-meaningful data because of low number of observations.

d) Innovation-cost intensity

Innovation-cost intensity - namely, current expenditures on innovation as a percentage of turnover - is one of the questions most frequently left blank by respondents. Many have had difficulties answering it, which makes for less reliable results. In addition, the data from some of the countries are not comparable. Of those which seem reliable we see that firms in the majority of countries - the execption being Italy - spend more on innovation if they are leaders compared to expenditures of laggards. The overall unweighted average intensity of expenditures in the countries is between 2-3%, with the Danish food and beverages industry being somewhat behind and the German industry somewhat ahead.

e) Share of unchanged products

The share of unchanged products in sales is one measure of innovativeness. The residual of the percentages in the table is the share of sales which are products new to the firm. There is no clear picture from the results.[20] The very clear differences between leaders and laggards in Germany, Portugal, Spain and Norway should not be taken as an indication of a relationship between growth in turnover and share of unchanged products. These differences can be explained by the special success criterion chosen for these countries. Of the remaining countries, Belgium and Ireland show better innovation performance by firms growing faster, whereas the Danish case shows the opposite, and there are differences between the two groups in the Netherlands and Italy. In other words, even if the evidence here is rather fragile, there seem to be indications that even firms who are somewhat behind technologically and perhaps experience negative growth rates are able to renew a large share of their product range. The results show that 20-40% of products change to some degree over the three-year period. This seems at first glance to reflect a major period of turbulence in the industry in terms of how fast the whole range of products changes. However, it must be remembered that the innovative products in the CIS data relate to the firm level. Therefore, it is possible - and likely - that a substantial part of the products *new to the firm* are imitations rather than products *new to the industry*.

Italy apparently has the least innovative food and beverages industry. This result is emphasized by the fact that it is also the country with the smallest share of innovative firms (cf. Table 2.1.2). The Irish food-processing industry is also in the lower part of the innovation spectrum. At the other end we find once more Germany, where products new to the firms account for about half of the sales.

f) R&D intensities

There are fewer observations in each cell when the focus is narrowed down to R&D-performing firms. The results with regard to R&D intensities is therefore less reliable. But the overall picture - with Belgium as the only exception - is of a very clear difference

[20] A correlation analysis between growth in turnover and share of unchanged products gives the same picture: correlation coefficients are generally low, in many cases insignificant, with the sign varying from country to country.

between leaders and laggards. Leaders are above laggards in close to all cases. In relating R&D intensities to other characteristics one can find relationships that are not easily explained. For example, Denmark is low in innovation-cost intensity but high in R&D intensity. Conversely, Ireland is high in innovation-cost intensity but low in R&D intensity. It could be that such differences relate to differences in the composition of innovation expenditures. In some countries innovation may require a high proportion of R&D compared to other countries.

g) Summarizing leaders and laggards

Leaders are - compared to laggards within the industry - technologically advanced in terms of their expenditures on both R&D and other innovation-related expenditures. This could perhaps result in a higher turnover per employee but not necessarily in higher shares of innovative products in sales. One hypothesis might be that the relatively technologically advanced leaders emphasize process innovations, in which case this will precisely show up in turnover per employee but not in the share of innovative products (however this is not supported by Table 6.2.1 below). The reverse causation factor could apply, with firms perhaps increasing their R&D expenditures as a result of high growth in turnover. It has been shown, though, that generally the share of R&D in turnover is rather constant, regardless of business cycles. So far as exports are concerned, it is not the status as leader or laggard that determines the export share of the firms but rather the size, geographical context and specialization of the home market.

The diversity of leaders and laggards is large both within the groups and between the groups. This goes in particular for the background variables, whereas the variables related to innovation show greater similarities among firms and between groups of firms.

6.2 Strategies 7.2. *Strategies*

Knowledge of strategies is valuable for the identification of appropriate policies because the emphases placed by firms on different objectives for their innovation activities to a large degree reflect the competitive environment in which they operate. Analysis of objectives for innovation may therefore indicate whether policies should mainly be directed towards supporting cost reduction (or other process-related activities) or product development.

As previously discussed, the traditionally held view of the food and beverages industry is that it is heavily process-oriented. In Table 6.2.1 below we show the means of the answers to the question in the CIS on different objectives of innovation, using an ordinal Likert scale. We would normally not use means for ordinal data as there may be discontinuous jumps in perceptions by the respondents as to how he/she should answer one of the 5 possible assessments. The usual way to treat ordinal data is to calculate the number of firms responding either “crucial” or “very significant”, relative to the total number of responses to the question. This “high-scores method” is used in subsequent analysis of the ordinal data. In this table we use the means in order to keep the maximum number of observations and because we group the questions into sub-categories. The 18 objectives listed in the questionnaire are grouped into three, covering product, process and marketing innovations.

6.2.1 Differences in objectives

The results show that product development objectives are as important as process development. In fact, there are remarkable similarities between the two. Results from the comparison of objectives indicates that product innovations and process innovations to a large degree go hand-in-hand in this industry. Only in Germany and Italy do we find significant differences between the two groups of objectives - in Germany product development being more important than process development, and *vice versa* in Italy.

Table 6.2.1:Mean ordinal scores by type of innovation

Country	*Ranking*	*Product development*	*Process development*	*Marketing development*
Belgium	Total	3.3	3.3	4.0
	Leaders	3.4	3.5	4.3
	Laggards	3.1	3.2	4.0
Denmark	Total	3.4	3.4	3.6
	Leaders	3.6	3.5	3.9
	Laggards	3.3	3.2	3.4
Germany	Total	3.4	2.9	4.6
	Leaders	3.3	3.0	4.8
	Laggards	3.1	2.7	4.4
Ireland	Total	3.4	3.3	4.0
	Leaders	3.5	3.1	4.1
	Laggards	3.4	3.3	3.9
Italy	Total	2.7	3.1	4.0
	Leaders	2.8	3.2	3.9
	Laggards	2.6	3.2	4.1
Netherlands	Total	3.3	3.0	4.1
	Leaders	3.3	3.1	4.3
	Laggards	3.3	3.1	4.0
Norway	Total	2.8	2.9	3.9
	Leaders	2.6	2.9	3.9
	Laggards	2.9	3.1	4.1
Spain	Total	2.5	3.2	4.6
	Leaders	2.6	3.3	4.9
	Laggards	2.6	3.1	4.3

Note: Calculated from CIS (Greece not comparable)

The levels of priorities are approximately similar across countries. Firms in Italy, Norway and Spain tend to focus less on product development compared to firms in other countries. With respect to process-innovation objectives there are smaller differences across countries. Marketing development is very important to firms in Germany and Spain, but not to firms in Denmark to the same extent.

Even more important than product- and process-related objectives are those objectives aimed at creating new markets. The importance attached to this objective is markedly higher than the importance of the other two groups. This is a further indication - supporting the findings in Chapters 2 and 5 - that this industry is particularly oriented towards the demand side, i.e. towards the users. In Section 7.1 we shall explore this issue further.

6.2.2 Differences between leaders and laggards

In all countries but Norway, and partly Italy, it seems as if leaders attached more importance to all three kinds of strategy. As with many other aspects of strategy one can only speculate as to the explanation of this result. Could it be that leaders are generally more conscious about choice of strategy? In any case, the gap between leaders and laggards is not striking, and results indicate at first sight that innovation objectives and success criteria chosen in this study are not strongly related. Although quantitative data have their limitations in terms of how far one can explore certain issues - and strategy is perhaps one of the more difficult - this preliminary conclusion requires some further examination.

This inquiry is undertaken in three steps. First, a correlation analysis is undertaken between the growth in turnover or share of innovative products in sales, and all the 18 possible innovation objectives. Results from this analysis are presented in Table 6.2.2 overleaf.

The conclusion to be drawn is that the correlation coefficients are generally low and insignificant. Across different innovation goals the magnitudes of the coefficient change, and the signs of the coefficient change according to which country is in question. Thus it is difficult to detect any clear pattern from these results.

Second, we try another success criterion. Assuming that firms without financial difficulties arising out of pursuing their innovation goals have had some success to be in such a position, we test for the relationship between financial resources as a barrier to innovation and the different innovation objectives. Both types of data are ordinal, unweighted data, and therefore we choose Kendall's *tau* correlation coefficients to compare all the objectives and three different but related financial barriers to innovation. These barriers are:

i) lack of appropriate sources of finance

ii) innovation costs too high

iii) pay-off period for innovation too long

If innovation strategies are to be of significant importance for the financial success - here the approximation of absence of financial constraint on innovation is used - we would expect certain innovation strategies to be related to this lack of financial barrier to innovation. If certain strategies are related to all three barriers this can be taken as a strong indication. However, again we find no patterns in the results. Signs of coefficients vary both between different objectives and between the above three barriers. Across countries we see no pattern in the results either. Furthermore, coefficients are low and in many cases insignificant.

Table 6.2.2:Correlation between innovation objectives and success criteria

Objective	*Belgium*	*Denmark*	*Germany*	*Ireland*	*Italy*	*Netherlands*	*Norway*	*Spain*
1	98	89	-96	81	19	-78	-36	-123
2	55	72	151	99	64	-56	-36	-131
3	78	-91	137	0.194*	29	-126	0.383*	-161
4	114	29	-135	-59	39	36	-4	-169
5	38	224	-100	82	0.097*	77	185	-63
6	39	-82	-133	179	27	-102	-131	na
7	69	3	9	70	-48	-17	na	na
8	9	11	-23	-15	-74	-20	na	na
9	-28	na	142	27	-37	-91	-231	na
10	165	-2	-72	123	58	26	72	-58
11	19	235	-110	38	65	-59	79	-121
12	-7	186	-0.236*	63	24	-41	35	4
13	78	81	-210	-66	79	16	23	-92
14	31	134	na	97	-3	-107	-83	-37
15	147	75	na	109	51	7	13	na
16	25	144	-129	74	45	16	-53	9
17	131	104	-0.238*	42	0.091*	111	-58	na
18	184	137	-118	-18	488	72	41	-102

Notes: All values represent Pearson's correlation coefficient.
* denotes significance at 5% level.

Objectives:

1 - replace products being phased out
2 - extend product range within main product field
3 - extend product range outside main product field
4 - increasing or maintaining market share
5 - create new markets nationally
6 - create new markets within the EU
7 - create new markets in North America
8 - create new markets in Japan
9 - create new markets in other countries
10- improve production flexibility

Lower production costs by:

11 - reducing the share of wage costs
12 - reducing materials consumption
13 - reducing energy consumption

14 - reducing design costs
15 - reducing production lead-times
16 - reducing environmental damage
17 - improving product quality
18 - improving working conditions/safety

Third, we divide strategies into offensive, defensive, dependent and imitative strategies (cf. Section 4.2.4) and subsequently compute the two different performance measures for these groups.

Table 6.2.3. shows main results from these calculations. The data are mean growth in turnover from 1990-92 for the first 5 countries and share of innovative products in turnover for Germany and Norway. In brackets the number of firms in each category is listed. It is not possible to group all the firms in each country equally according to the four types of strategies if the strategies are to be consistently comparable across countries. Therefore, in some cases not all of the innovative firms in a country are placed in one of the groups and in other cases there are firms which could be placed equally well in two groups.

Table 6.2.3: Success criteria distributed according to different strategies, Percentages

	Strategy ->	Offensive	Defensive	Dependent	Imitative
Country	**Variable**				
Belgium	Growth turn-over	12 (N=20)	23 (N=33)	18 (N=17)	27 (N=25)
Denmark	Growth turn-over	25 (N=14)	26 (N=14)	28 (N=19)	24 (N=13)
Ireland	Growth turn-over	21 (N=32)	23 (N=35)	11 (N=12)	9 (N=13)
Italy	Growth turn-over	Not com-parable	21 (N=97)	21 (N=71)	20 (N=117)
Netherlan ds	Growth turn-over	15 (N=40)	17 (N=38)	15 (N=30)	16 (N=67)
Germany	Share of innovative products	41 (N=15)	46 (N=38)	49 (N=30)	42 (N=54)
Norway	Share of innovative products	28 (N=14)	30 (N=16)	40 (N=14)	41 (N=19)

Calculated from CIS
Greece, Portugal, Spain not comparable

Standard deviations vary between 22 and 46.

There are several dimensions in this table. First, the four strategies show no clear pattern with respect to which one is the most successful. The offensive strategy is in no case the most successful but is not far from the average execpt in the case of Belgium. As the success criterion used refers to the same period as the innovation objectives and as the offensive strategy presumably has the longest time-lag between strategy and success, it is not surprisingly that this strategy does not come out as the most successful. Of the remaining strategies they are ranked the most successful in two cases each.

Second, within some of the countries there are clear differences between the success of the strategies (Belgium, Ireland) whereas the other countries show only small differences in the outcome of pursuing one of the 4 innovation strategies.

Third, the distribution of firms according to the 4 strategies is interesting. Apparently the imitative strategy is the one most frequently used - at least in the majority of the countries (Italy, Netherlands, Germany, Norway). Within some of the countries there are quite clear differences between the number of firms grouped in the different categories. For example, most Irish firms use an offensive or defensive strategy whereas the majority of firms in Netherlands and Germany pursue imitative strategies.

The general conclusion from the various attempts to investigate this issue is that results are rather blurred with respect to differences between leaders and laggards.[21] This leads us to conclude that, on the basis of the present data, we cannot identify significant differences in strategies between leaders and laggards. It may well be that some relationships exist, but we have not been able to identify them with quantitative methods and the present data. What we do find is a remarkable emphasis on goals of creating new markets, which encourages us to go further in investigating the importance of the relationships between users and producers, and on an even higher level of aggregation the importance of the national innovation system. That investigation will be presented in Chapter 7. Before moving to that chapter we explore another issue at the firm level, namely the relationship between profitability and innovation.

6.3 The relationship between innovation and profitability

6.3.1 Introduction: an inverse relationship?

Economic explanations of innovation and diffusion rest heavily on the search for profits. It has been explained in Chapter 3 above that innovations are likely to be associated with the desire to obtain higher profits. According to the theory, new products and processes generate monopolistic rents for a period, until competitors are able to imitate them and erode the rents. In view of the prospective importance of this relationship, it is explored at some length in this section of the report. A second reason for going into this matter in

[21] Size of firm does not seem to play an important role in choice of strategy either (based on both frequency analysis and correlation analysis).

some detail is that we can include the UK and France in the analysis - two important countries that we were unable to analyze adequately with CIS data.

Although most empirical studies have confirmed the hypothesis of relationships between innovation and profitability, it is unclear whether these hold in every industry. Most studies have investigated high-tech industries, where there is more likelihood of new technology creating monopolistic conditions for the innovators. However traditional industries, amongst which we can count food and beverages (food-processing), incorporate a great deal of both internal innovations and those produced by other industries (Rama, 1996; and Chapter 5 above). Extraordinary gains may be short-lived because new products and processes are comparatively easy to imitate (OECD, 1988). Modest technological change is often more common than "creative destruction" in such industries. Unlike in high-tech industries, non-innovators might also regularly obtain monopolistic gains, through differentiation of products, advertising or control of natural resources; in other words, firms might made high profits with strategies other than innovation. To conclude, the association between innovativeness and profitability in food-processing is likely to be more tenuous than in high-tech industries.

The issue nevertheless may be crucial. If manufacturers fail to find reasons to innovate like high profits or similar advantages, public policies for technology are likely to be of limited commercial value.

Previous research does not provide enough evidence on traditional industries with low R&D intensities (R&D expenditures relative to sales). Branch (1974), for instance, deliberately excludes the food-processing industry from his analysis of innovation and performance because he does not expect to find any association between these variables. The few studies that do tackle the problem reach contradictory results, probably owing to differing samples and methods (Geroski *et al.*, 1993; Rama, 1994).

In similar vein, a case study on the Danish firms in the CIS sample shows seemingly inverse results with respect to the relationship between innovation and profitability. Using the original CIS dataset and combining it with official accounts reported at the firm level, we have measured the profitability of firms in the Danish food-processing industry. (This possibility of combining CIS data with such other material at the firm level is only possible for Norway and Denmark). Two measures of profitability were used:
i) return on equity, and
ii) pretax results relative to total assets.

Firms were divided into the groups of innovators and non-innovators in 1990-1992. The time-lag between innovation and economic performance is of course uncertain and may vary among firms. In this analysis the 1994 accounts have been used.

Table 6.3.1 : Danish innovator and non-innovator firms and profitability

A) percentage return on equity

	No.	Mean	Std. Devn.
All	70	12.6	18.5
Innovative	41	11.2	17.1
Non-innovative	29	14.4	20.1

B) pretax returns as percentage of total assets

	No.	Mean	Std. Devn.
All	70	7.9	10.2
Innovative	41	6.7	10.7
Non-innovative	29	9.6	9.3

By either measure, the hypothesis of a positive link is rejected. Indeed, the means for the non-innovating group lie substantially above those for the innovators.

6.3.2 Objectives of the analysis

This section aims to identify structural differences between large innovative and non-innovative firms in the international food-processing industry. It also investigates how performance and strategy, such as methods of financing growth, are associated with innovativeness at the firm level. In this respect, the previous analysis of innovation strategy in Section 6.2 is extended to include financial strategy. The study focuses on a group of the world's largest firms in food-processing, with special emphasis on European firms.

The core issues are:

a) whether factors such as size, branch of industry, or home country affect how innovation and profitability are associated;

b) whether firm strategies influence the path to profitability through innovativeness for the firm: e.g. by less innovative firms needing to balance their technological inadequacy with financial strategies which may involve less independence, greater risk and so on.

A number of difficulties should be borne in mind when assessing the results of this study.

a) Innovation is just one among many factors that might lead to high profits in the food-processing firm. Financial and marketing strategies are also obviously influential. To incorporate these would require the examination of a great number of interrelated variables, which would additionally make it difficult to design clear-cut experiments.

b) This section of the Report analyses only internal innovations, i.e. innovations patented by large food-processing firms in our sample. This is a drawback because external innovations, i.e. innovations produced by suppliers and other firms at the 2-digit industry level, are vital (Scherer, 1989; Rama, 1996; and Chapter 5 above) and highly favourable to obtaining profits in this industry, including those achieved by non-patentors (Rama, 1994). Nor does the sample (owing to data unavailability) include patents produced by specialized firms performing R&D under contract from food and drink firms, a pattern which appears to be common in biotechnology (Chesnais and Walsh, 1994). The important issue of the "innovation system" in this industry is dealt with in Chapter 7.

c) Another area where authors disagree is over reverse causation, i.e. the situation in which profits affect subsequent R&D. This possibility is thought to be remote in large firms, where finance of R&D does not appear to be a serious constraint, and in which R&D is usually funded from internal sources (Acs and Isberg, 1991a; Himmelberg and Petersen, 1994). The R&D budget of small firms may be more subject to economic fluctuations (Kay, 1979). After a review of the literature on this topic, Kamien and Schwartz (1975) concluded that "the empirical evidence that either liquidity or profitability are conducive to innovative effort appears slim". In this part of the Report, the causal direction to be studied is the influence of innovation on profit, not the other way around.

6.3.3 Data and sources

The sample includes 101 food and drink multinationals, from a variety of home countries, with worldwide sales of at least US$ 1 billion in 1988 (see Appendix 6.1). All are processors; a number of them also include agri-businesses, restaurants or retail concerns among their holdings. In all cases the sales value of processed foodstuffs is what is relevant. Firms with non-food sales greater than 50% of their global sales were excluded. Drink firms include soft drinks, beer and alcoholic beverages. The data were selected from AGRODATA, a database covering the world's largest food and drink firms (Padilla *et al.*, 1983; IAM, 1990).

The patent data were collected by the Science Policy Research Unit (SPRU) at the University of Sussex. This database provides information on patents granted in the United States, collated at the firm level. The sample of firms includes both patentors and non-patentors, judged by this criterion. The merits and limitations of patents data as the measure of innovation have been discussed previously in Chapter 4.

The period analysed is 1977-88. Though sales data for the 1990s are not yet available, this period probably reflects the current situation. Technological trends change relatively slowly owing to conservative consumers and prudent public policy in this industry (OECD, 1988). For reasons already described, namely the possibility of variation over the business cycle, the whole period has been divided into three sub-periods, the first being a period of expansion, the second one of crisis, and the third witnessing recovery.

Table 6.3.2: Definition of the Variables

Variable	Description
Economic Variables	
Assets	Global assets in current US$
Capital Intensity	Fixed Assets / Number of Employees
Employment	Total number of employees
Fixed Assets	Global fixed assets in current US$
Gearing	(Long-Term Debt + Short-Term Debt) / Own Capital
Industry	Firms are classified by the subsector in which they concentrate most of their sales. There are three subsectors: 1) Agri-businesses and basic food (sugar, grain milling, meat, aviculture, fisheries and animal feed); 2) Highly-processed food; 3) Beverages (soft-drinks, beer and alcoholic drinks)
Margins	Net post-tax Profits / Sales
Own Capital	Total shareholders' equity in current US$
Product Diversification	Number of food and drink products produced by the firm (4-digit level).
Profits	Net post-tax Profits / Own Capital
Rotation of Capital	Global Sales/Own Capital
Sales	Global sales in current US$
Technological Variables	
Biotechnology	Percentage of biotechnological patents to total number of patents issued to the firm
Diversification	No. of technological fields other than food and biotechnology in which the firm is active (measured at the two-digit level)
Experience	Percentage of patents issued in 1969-76
Food	Percentage of food patents to total number of patents issued to the firm
Innovative intensity	Number of patents per billion-dollar of sales
No. of Patents	Number of patents granted to the firm in the US

6.3.4 Country and time patterns

Before undertaking the formal analyses, we shall discuss a few aspects relating to differences across countries and evolution over time, for such variables as size, profit, fixed assets and capital structure, and for the variables used to assess technology levels.

The information provided in Tables 6.3.3 and 6.3.4 overleaf (based on the definitions of variables listed in Table 6.3.2) allows us to draw some broad conclusions about economic and technological features of the industry. Economic features of the firms in this fairly comprehensive sample of very large firms have changed rather quickly, as seen in Table 6.3.3. On average, firms grew larger, increased their expenditures in the means of production, and performed better as time progressed. Though they obtained more equity, gearing also increased. There was a considerable and quite rapid substitution of labour by capital. Table 6.3.4 shows that the total number of patents per firm increased, as did the percentage of biotechnological patents in the total. However, patenting grew more slowly than sales, assets and so on. Therefore firms became less innovation-intensive, i.e. the annual number of patents per billion dollar of sales tended to drop. Thus technological behaviour, by this measure, remained more stable than did economic behaviour.

6.3.4.1 Economic features

Size

The average size per firm, measured by global annual sales, increased from US$ 2.8 bn in 1977-81 to US$ 3.6 bn in 1982-85 and to US$ 5.2 bn in 1986-89. Though their sales had been above those of the average large food and drink firm in 1977-81, European firms grew less rapidly than the others and suffered more in this respect from the crisis of the early 1980s. After recovery, their average sales fell below and remained lower than those of the non-European firms. Average assets experienced a similar evolution (see Table 6.3.3).

Some food-processors were more successful than others in growing in size. The variability of size of the average firm increased over that period, as shown by the standard deviation of the variable (column 4 of Table 6.3.3, for sales). The distribution of sizes actually became more and more skewed towards very large firms. The rise in the numbers of giant firms was a consequence of both the expansion of existing food enterprises and the entry of giant non-food corporations, such as some tobacco companies, into the food and drink market. The standard deviation of the sizes of European firms also increased significantly in the later 1980s (column 7 of Table 6.3.3).

Table 6.3.3: Descriptive Statistics of Economic Data (1977-81, 1982-85, 1986-89)

VARIABLES	PERIOD	Total	Mean	Std. Dev.	Total*	Mean*	Std. Dev.*
Assets	1977-81	79	1644	1841	28	1915	2527
	1982-85	97	2222	2844	39	1672	2432
	1986-89	97	3682	4321	40	3352	4373
Fixed Assets	1977-81	78	807	840	28	894	990
	1982-85	94	1211	1700	38	792	1034
	1986-89	96	2059	2686	39	1608	2036
Own Capital	1977-81	78	733	868	28	850	1111
	1982-85	97	908	1126	39	747	1139
	1986-89	97	1370	1560	39	1370	1723
Long-term Debt	1977-81	78	374	470	28	388	595
	1982-85	95	622	1127	38	359	530
	1986-89	96	1141	1726	39	850	1300
Short-term Debt	1977-81	78	541	617	28	670	881
	1982-85	94	718	827	38	596	827
	1986-89	96	1174	1352	39	1193	1666
Sales	1977-81	82	2800	2936	30	3055	4077
	1982-85	101	3608	4216	42	2784	3772
	1986-89	101	5196	5825	42	4379	5441
Net Profit	1977-81	81	103	134	29	98	140
	1982-85	96	138	216	39	98	148
	1986-89	97	252	337	39	261	346
Net Cash Flow	1977-81	78	169	196	28	173	233
	1982-85	94	229	301	38	168	242
	1986-89	96	391	469	39	375	467
No of Employees	1977-81	81	34503	47468	30	43643	67914
	1982-85	99	33900	44468	40	33117	51946
	1986-89	99	36667	46844	41	35253	54096
Profit (%)	1977-81	78	13.4	6.2	28	12.5	6.2
	1982-85	95	12.8	7.4	39	12.9	7.3
	1986-89	94	16.7	9.9	38	18.5	10.1
Margins (%)	1977-81	81	3.2	2.0	29	3.2	1.8
	1982-85	96	3.5	3.7	39	3.7	4.4
	1986-89	96	4.3	3.1	38	4.8	3.1
Cashflow/Assets	1977-81	78	10.6	4.4	28	10.1	5.3
	1982-85	94	10.8	9.6	38	11.2	14.6
	1986-89	96	12.2	17.5	39	15.3	27.2
Gearing	1977-81	78	1.78	2.06	28	1.50	1.12
	1982-85	94	2.08	2.34	38	2.09	1.71
	1986-89	96	2.27	2.14	39	2.15	1.69
Capital Intensity	1977-81	78	35.3	59.7	28	26.6	18.6
	1982-85	94	48.6	61.6	38	28.1	14.6
	1986-89	96	75.7	74.6	39	50.5	30.4
Capital Rotation	1977-81	78	6.0	5.3	28	5.5	4.9
	1982-85	97	7.0	6.7	39	7.4	6.4
	1986-89	96	6.0	4.8	39	6.1	4.7

Note: All monetary variables expressed in US$m.
* European firms only

Table 6.3.4: Descriptive Statistics of Technological Data (1977-81, 1982-85, 1986-89)

VARIABLES	PERIOD	Total	Mean	Std. Dev.	Total*	Mean*	Std.Dev.*
No. of Patents	1977-81	82	5.8862	15.838	30	5.0933	15.185
	1982-85	101	6.3218	18.420	42	4.0040	13.433
	1986-89	101	7.0677	18.903	42	4.6944	15.297
Diversification	1977-81	82	1.9628	2.5729	30	1.4500	2.5728
	1982-85	101	1.8160	2.7023	42	1.0952	2.1871
	1986-89	101	1.9299	2.5211	42	1.3433	2.3682
Experience	1977-81	82	34.566	24.746	30	33.709	26.790
	1982-85	101	32.196	25.107	42	30.653	27.200
	1986-89	101	32.196	25.107	42	30.653	27.200
Biotechnology	1977-81	63	5.4952	12.149	20	5.3415	12.812
	1982-85	76	4.2005	11.004	29	3.6931	9.9372
	1986-89	79	7.7676	20.202	30	7.5483	25.323
Food	1977-81	63	30.613	29.472	20	22.004	24.187
	1982-85	76	39.130	38.417	29	45.095	44.053
	1986-89	79	34.296	34.834	30	35.240	39.135
Innovative intensity	1977-81	82	.18209	.30934	30	.15227	.36136
	1982-85	101	.12270	.20855	42	.08453	.17312
	1986-89	101	.09314	.14718	42	.05520	.09901

Note: Variables are defined in Table 6.3.2.
* European firms only

Differences in origins of capital and the types of subsector involved contribute to explaining differences in firm size. US firms, which are on average the largest, enjoyed rapid increases in the scale of output. European firms, which are smaller on average, enjoyed less dynamic growth; moreover they developed relatively late, showing sharp rises in sales only after 1985. Finally, Japanese firms, which are the smallest in the sample, exhibited steady if unspectacular growth from the very start.

Although firms in all subsectors showed good performances, firms producing high value-added foodstuffs were the most successful in growing in size (the industry boundaries are defined in Table 6.3.2). The success of this group, the average sales of which increased from US$ 3.5 bn in 1977-81 to US$ 5.5 bn in 1986-89, was a result of changes in lifestyles and costly mass-media campaigns (see also Chapter 5 above). The size of firms processing basic food and agri-businesses increased from US$ 2.1 bn to US$ 5.1 bn. Finally, the size of the average beverage firm grew from US$ 2.4 bn to US$ 4.6 bn over the same period.

Employment

Another measure of the size of an enterprise is employment. Average employment grew slowly throughout the period investigated in this section. The rather slight increases in the number of workers under conditions of a booming demand may be explained by a substitution of labour by capital. This process was much more intense in European enterprises as the number of employees fell sharply throughout the period. The shift towards large firms that was seen in the sales and assets data are much less marked in terms of employment data.

Fixed assets
In the sample, investment grew with sales. The fixed assets of the average large firm rose from US$ 0.8 bn in 1977-81 to US$ 1.2 bn in 1982-85 and US$ 2.1 bn in 1986-89. The evolution was less steady in European firms, with the big increase limited to the later 1980s.

Profitability
The statistical analysis confirms the view that the rate of profit of food-processing firms was relatively immune to the crises. The average rate of profit, i.e. the net profit/own capital ratio, declined only slightly from 13.4% in 1977-81 to 12.8% in 1982-85, to climb quickly to 16.7% over the second half of the 1980s. Margins, i.e. the net profits/sales ratio, were more resilient to the crisis. European firms were even more successful: their profits rose slightly during the crisis and their recovery was more vigorous (Table 6.3.3).

As could be expected, given the evolution of the demand, profits were especially strong in highly-processed foods (rising from 13.3% to 18.0%) while gains were smaller in beverages (from 13.6% to 16.3%) and basic food as well as agri-businesses (from 13.4% to 17.0%).

The profit measure separates out capital payments and adjusts the cash surplus or deficit so as to match up revenues with costs. This measure also includes costs incurred but not yet paid and the benefits obtained from sales invoiced but not yet received. For these reasons, the profit measure may be somewhat manipulated. More importantly in international comparisons, it can be affected by different taxation or accounting systems. This problem, however, affects international comparisons of single-nation firms to a greater extent than those of multinationals based in different home countries. Part of the revenue of multinationals is subject to different accounting methods and taxation systems in a variety of host countries. This circumstance presumably smoothes the home-country bias and thus justifies the use of the profit measure in international comparisons. To check this point we calculated a measure of profitability based on cash flow, i.e. cash flow/assets. As shown by Table 6.3.3, the results are similar. The cash-flow measure also points to continuous increases in profitability in all types of firms, not just in the European ones. It confirms, moreover, that the latter have performed better than average in these terms after 1982.

The portion of firms enjoying very high profit rates, defined as more than 20%, increased notably, from only 9% of the total number of firms in 1977-81 to nearly 30% in 1986-89 (these results are not displayed in the Tables given here). However, most firms remained in the medium-profit bracket, with rates of profit from 11% to 20%. Japanese firms were an exception because their profits were consistently rather low, i.e. 10% or less, and the proportion of firms getting low returns increased from 75% to 93% of the total number of Japanese firms. A cross-classification of firms by cash flow/assets and country confirms that returns are lower in most Japanese firms.

Equity and debt
The statistical analysis confirms the view that the resources available to firms expanded significantly. New investors gave a boost to the amount of own capital per firm, although debt also grew. The average amount of equity more than doubled in all firms from 1977-

81 to 1986-89; it also grew in European firms, after a drop up to the mid-1980s (Table 6.3.3).

Even though the cost of capital was high throughout these years, debt also played a major role in the financing of development. Average long-term debt more than tripled from 1977-81 to 1986-89. Increases in short-term debt were also significant. European firms kept debt more in check although it grew fast towards the end of the period.

As a result of these developments, the financial structure of firms changed and debt became more and more vital. The table thus shows gearing increasing quickly over this period in both European and non-European firms.

Cash Flow
The ratio of net cash-flow to assets and the average availability of cash per firm rose sharply. The performance of European firms was noteworthy.

Capital to Labour Ratio
The statistical analysis confirms the opinion that capital intensity has increased in this international industry. The evolution of the capital/labour ratio, i.e. the ratio of fixed assets to number of employees, suggests a quick incorporation of technology embodied in new capital goods. The move towards processes based on the intensive use of capital is also pronounced among European firms in the later 1980s, even if they remained less capital-intensive than other firms (Table 6.3.3).

6.3.4.2 Technological features

Number of patents
The total number of patents issued to all firms increased, on average, from 5.9 a year in 1977-81 to 7.1 in 1986-89. By contrast, in European firms, the average dropped from 5.1 a year to 4.7 over the same period (Table 6.3.4).

At first sight, the economic re-organization of this international industry has induced no marked moves in the technological position of firms. Firms have tended to concentrate in intermediate strata, with most having 2-3 patents issued a year. The extremes, i.e. groups with very low patenting (under 2 a year), or very high patenting (above 10 a year), lost importance as proportions of the total number of firms (data not displayed).

The gap between US firms and other firms has tended to close. In 1977-81, patenting involvement of US firms was notable by comparison with other firms; though one has to allow for the fact that the USA is the “home country” for US firms, so one would expect higher patenting levels, *cet. par*. Only 3% of US firms had, on average, under 2 patents a year. By contrast, from 31% to 44% of non-American firms did so over the same period. This situation has changed. Over time, the portion of firms less involved with patenting increased among US firms and decreased among non-US firms. Increases in patenting activity were especially noticeable among Japanese firms. The proportion of firms with under 2 patents a year dropped from 31% to only 18% of the total number of Japanese firms over the period. The proportion of firms with under 2 a year fell a little from one-third to under 29% of European firms. This change could denote, although to a much lesser degree, some increase in patenting activity in European firms as well. However, the percentage of lesser patentors remained quite high among European processors by the end of the 1980s, if compared with both Americans and Japanese. One cannot completely exclude the possibility - even if these firms have long had business experience in the US - that what has increased is, in fact, their foreign patenting rather than their innovative output in total.

Biotechnology
The share of biotechnological patents on the total number of patents per firm grew both in the average firm worldwide and in the European one. Yet, in both cases, there was a reduction of the percentage of biotechnological patents over 1982-85 (Table 6.3.4). As will be suggested below, during the crisis firms may have withdrawn from the more peripheral activities, such as biotechnology, to concentrate on food technology.

Food
The share of food patents in the total number of patents increased in the average firm, and especially in the European firms which became much more specialized after 1982 (Table 6.3.4). In both cases, food technology was remarkably strengthened over 1982-85, probably as a consequence of concentration in core businesses throughout the crisis.

Diversification
The level of diversification into technological fields other than food and biotechnology is rather low throughout the period, especially in European firms; the general pattern (as demonstrated elsewhere in this Report) is towards a reduction of diversification (see also von Tunzelmann, 1996).

Innovative intensity
This variable shows the number of patents issued to a firm per billion dollars of sales. Technological intensity has decreased sharply. It was reduced to less than one-half of its initial value (1977-81) in all firms by the final period (1986-89), and to less than one-third in European firms over the period; although in the latter case the number of included firms rose and this may account for part of the decline. The variable is analyzed at length in Section 6.3.5.2 below.

6.3.4.3 Conclusions

1. The evolution of innovation has not reflected the more rapid economic changes experienced by firms during the 1980s. Moreover, innovative intensity of firms has dropped in spite of increases in equity and profitability, which the theory associates with high levels of innovativeness. Factors driving competition in this industry seem to be market size, fixed assets and capital intensity rather than innovativeness. Contrary to the assumptions of Utterback and Suárez (1991), exacerbation of competition has not led to rapid technological change, unless relatively stable patenting behaviour conceals other forms of incorporation of technology.

Some possible explanations for the apparent stability of innovation are:

a) Firms have preferred to aim at massive adoption of external innovations, notably in capital goods, rather than on patenting of their own innovations. This interpretation is suggested by the rapid growth of fixed assets, the slow growth of employment and the increased capital-labour ratio.

b) Production of internal innovations increased but appropriation regimes changed. Food-processing firms have preferred to finance R&D contracts with specialized firms rather than to conduct in-house research. According to Aghion and Tirole (1994), when intellectual inputs (relative to capital inputs) dominate, as in biotechnology, research will often be carried out by independent units.

c) Firms have relatively stable R&D expenditures. One of the objectives of their expansion has been precisely that of spreading these fixed costs over a broader base (Connor and Schiek, 1996). If this interpretation were correct, a fall in innovative intensity would denote success by the firm in spreading its costs.

2. Some changes experienced by firms are, in principle, favourable to innovation while others are adverse. Average size and availability of internal funds, which are thought to encourage growth in R&D expenditures, have increased. Yet gearing, which is believed to discourage R&D, has also increased.

6.3.5 Leaders and laggards

This section investigates the evolution of patenting activity in the world's largest food-processing firms, as the group already studied above. The inquiry is pertinent to the pattern of technological change in this industry. Even if the contribution of smaller firms and universities happens to be significant for innovation more broadly, large multinational firms play a crucial role in the production of patented innovations in this industry (Rama, 1996). There are thus good reasons to study the largest patentors in greater detail.

Second, we investigate whether innovative firms display any particular characteristics in terms of size, profits, comparative profitability, subsectoral membership, or home country.

Table 6.3.5: Food and Drink Firms Classified According to Patenting Activity and Assets
(1977-81, 1982-85, 1986-89; percentages of column totals)

No of patents per firm	Non-patentor	3	>3 10	>10	Total
1977 - 1981					
< US$ 1 b	70.6 %	52.6 %	27.3 %	15.4 %	46.8 %
US$ 1.1 b - 2.0 b	17.6	34.2	36.4	23.1	29.1
US$ 2.1 b - 4.0 b	11.8	10.5	27.3	38.5	17.7
> US$ 4.0 b	0.0	2.6	9.1	23.1	6.3
1982 - 85					
< US$ 1 b	58.3 %	53.2 %	14.3 %	8.3 %	43.3 %
US$ 1.1 b - 2.0 b	12.5	31.9	7.1	16.7	21.6
US$ 2.1 b - 4.0 b	25.0	8.5	50.0	16.7	19.6
> US$ 4.0 b	4.2	6.4	28.6	58.3	15.5
1986 - 89					
< US$ 1 b	42.9 %	29.2 %	0.0 %	0.0 %	23.7 %
US$ 1.1 b - 2.0 b	23.8	29.2	26.7	0.0	23.7
US$ 2.1 b - 4.0 b	28.6	16.7	46.7	15.4	23.7
> US$ 4.0 b	4.8	25.0	26.7	84.6	28.9

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	79	97	97
DF	9	9	9
Pearson Chi-square	20.40	43.41	37.65
P-value	0.0156	0.0000	0.0000

Table 6.3.6: Food and Drink Firms Classified According to Patenting Activity and Sales
(1977-81, 1982-85, 1986-89; percentages of column totals)

No of patents per firm	Non-patentor	3	>3 10	>10	Total
1977 - 1981					
< US$ 1.5 b	68.4 %	43.6 %	18.2 %	15.4 %	41.5 %
US$ 1.6 b - 3.6 b	5.3	53.8	45.5	15.4	35.4
US$ 3.7 b - 6.0 b	26.3	2.6	27.3	38.5	17.1
> US$ 6.0 b	0.0	0.0	9.1	30.8	6.1
1982 - 85					
< US$ 1.5 b	32.0 %	44.0 %	14.3 %	0.0 %	31.7 %
US$ 1.6 b - 3.6 b	32.0	42.0	21.4	33.3	35.6
US$ 3.7 b - 6.0 b	20.0	10.0	35.7	8.3	15.8
> US$ 6.0 b	16.0	4.0	28.6	58.3	16.8
1986 - 89					
< US$ 1.5 b	18.2 %	20.0 %	6.7 %	0.0 %	14.9 %
US$ 1.6 b - 3.6 b	50.0	44.0	26.7	7.1	37.6
US$ 3.7 b - 6.0 b	22.7	14.0	40.0	21.4	20.8
> US$ 6.0 b	9.1	22.0	26.7	71.4	26.7

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	82	101	101
DF	9	9	9
Pearson Chi-square	43.95	32.60	26.44
P-value	0.0000	0.0002	0.0017

6.3.5.1 The Most Important Patentors

a) Number of Patents Granted and Size

As could be expected, patented innovation tends to be produced predominantly by large firms. Tables 6.3.5 and 6.3.6 display the distribution of firms according to different levels of patenting activity, measured respectively by their assets and sales as alternative indicators of the size of the enterprise. Levels of patenting are defined by the average number of patents granted to the firm per year, based on the 4-year totals.

Most non-patentors are included among the smaller of these large firms in the opening period (1977-81), which remains true thereafter, although their share tends to decline later while the medium-sized increase their share of non-patenting. The latter is especially true when we use sales to measure the size of the firm. By contrast, heavy patentors, i.e. firms with more than 10 patents per year, are likely to be very large, and moreover tend to concentrate even more in the larger-size categories over time.

The Pearson chi-squared statistics at the bottom of each of these tables are used to test for independence between the row and the column variables. In both tables, the test allows the rejection of the hypothesis of independence between size and average number of patents per firm, with significant probability values (mostly under the 1% level) in each sub-period. It may reasonably be concluded that the number of patents issued to a firm and its size are strongly interrelated.

b) Number of Patents Granted and Profitability

Firms that produce a great number of patents tend to be profitable. Table 6.3.7 contains data of the cross-classification of firms into three profit levels and four patent levels. The chi-squared test, which allows rejection of the hypothesis of independence between the number of patents and the rate of profit, is significant at under the 10% level, except in 1986-89.

A refinement of this result is presented in Table 6.3.8, where we calculate a new variable measuring the rate of return over and above the average, called "comparative profitability" (Geroski and Jacquemin, 1988). This variable is the difference between the firm's profit and average profit rates in the subsector within which the firm concentrates most of its sales. Firms were cross-classified into the previous four patent categories and into two levels of comparative profitability, depending on whether they made profits higher or lower than the average. Then we tested the homogeneity of the proportion for different levels of patenting activity. The null hypothesis of independence of the variables could be rejected at under the 10% level for 1977-81, 1982-85 and 1986-89. This suggests that the number of patents granted to a firm are interrelated with its comparative profitability.

Although heavy patentors are likely to be highly profitable, conversely, it is interesting to note that a surprisingly large share of highly profitable companies are low patentors or even non-patentors (see Table 6.3.9, which calculates percentages of the row rather than

Table 6.3.7: Food and Drink Firms Classified According to Patenting Activity and Profit (1977-81, 1982-85, 1986-89; percentages of column totals)*

No of patents per firm	Non-patentor	3	>3 10	>10	Total
1977 - 1981					
10%	31.3 %	34.2 %	27.3 %	7.7 %	28.2 %
11% - 20%	43.8	60.5	72.7	84.6	62.8
> 20%	25.0	5.3	0.0	7.7	9.0
1982 - 85					
10%	43.5 %	39.1 %	28.6 %	8.3 %	34.7 %
11% - 20%	43.5	52.2	71.4	50.0	52.6
> 20%	13.0	8.7	0.0	41.7	12.6
1986 - 89					
10%	35.0 %	26.1 %	33.3 %	7.7 %	26.6 %
11% - 20%	45.0	50.0	26.7	38.5	43.6
> 20%	20.0	23.9	40.0	53.8	29.8

* Net profit/own capital

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	78	95	94
DF	6	6	6
Pearson Chi-square	10.77	14.99	8.27
P-value	0.0958	0.0203	0.2189

Table 6.3.8: Food and Drink Firms Classified According to Patenting Activity and Comparative Profitability (1977-81, 1982-85, 1986-89; percentages of column totals)*

No of patents per firm	Non-patentor	3	>3 10	>10	Total
1977 - 1981					
Below Average	75.0	65.8	54.5	23.1	59.0
Above Average	25.0	34.2	45.5	76.9	41.0
1982 - 85					
Below Average	60.9	63.0	35.7	16.7	52.6
Above Average	39.1	37.0	64.3	83.3	47.4
1986 - 89					
Below Average	70.0	69.6	53.3	30.8	61.7
Above Average	30.0	30.4	46.7	69.2	38.3

* Net profit/own capital (as compared with sub-sector averages)

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	78	95	94
DF	3	3	3
Pearson Chi-square	9.44	10.46	7.50
P-value	0.0240	0.0150	0.0577

Table 6.3.9: Food and Drink Firms Classified According to Patenting Activity and Profit (1977-81, 1982-85, 1986-89; percentages of row totals)*

No of patents per firm	Non-patentor	3	>3 10	>10	*Total*
1977 - 1981					
10%	22.7 %	59.1 %	13.6 %	4.5 %	*100 %*
11% - 20%	14.3	46.9	16.3	22.4	*100*
> 20%	57.1	28.6	0.0	14.3	*100*
TOTAL	20.5	48.7	14.1	16.7	*100*
1982 - 85					
10%	30.0 %	54.5 %	12.1 %	3.0 %	*100 %*
11% - 20%	20.0	48.0	20.0	12.0	*100*
> 20%	25.0	33.3	0.0	41.7	*100*
TOTAL	24.2	48.4	14.7	12.6	*100*
1986 - 89					
10%	28.0 %	48.0 %	20.0 %	4.0 %	*100 %*
11% - 20%	22.0	56.1	9.8	12.2	*100*
> 20%	14.3	39.3	21.4	25.0	*100*
TOTAL	21.3	48.9	16.0	13.8	*100*

* Net profit/own capital

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	78	95	94
DF	6	6	6
Pearson Chi-square	10.77	14.99	8.27
P-value	0.0958	0.0203	0.2189

column totals). This is especially noteworthy in 1977-81: for instance, 57% of highly profitable firms were non-patentors. Towards the end of the 1980s, the proportion of highly profitable firms with under 3 patents granted a year tends to drop but remains considerable. This latter evolution probably indicates that innovation is becoming more important to competition than it used to be. In short, while firms holding a great number of patents are likely to be highly profitable, the reverse is not always true. Highly profitable businesses are not necessarily major patentors.

c) Number of Patents Granted, Countries and Industries

With which industries and countries are the principal patentors associated? The analysis of the combined effects of country and industry contributes to minimizing the possibility of a home-country bias, a possibility alluded to in Section 6.3.4.2. However, in what follows, comparisons between US and non-US firms should be treated with a degree of caution, in the light of such possible biases.

Table 6.3.10: Cross-classification of Food and Drink Firms by Average Number of Patents, Industry and Home-Country (1977-81, 1982-85, 1986-89; percentages of column totals)

Industry	Home Country	Non-patentor	3	>3 10	> 10	Total
1977-1981						
Basic Food and Agri-businesses	US	5.3 %	12.8 %	9.1 %	23.1 %	12.2
	Eur	5.3	12.8	9.1	0.0	8.5
	Jap	15.8	7.7	0.0	0.0	7.3
	Other	5.3	0.0	9.1	0.0	2.4
Highly-processed Food	US	0.0	23.1	27.3	38.5	20.7
	Eur	36.8	12.8	0.0	23.1	18.3
	Jap	0.0	2.6	18.2	7.7	4.9
	Other	15.8	2.6	0.0	0.0	4.9
Beverages	US	0.0	0.0	18.2	7.7	3.7
	Eur	10.5	12.8	9.1	0.0	9.8
	Jap	5.3	5.1	0.0	0.0	3.7
	Other	0.0	7.7	0.0	0.0	3.7
	TOTAL	*100*	*100*	*100*	*100*	*100*
1982-1985						
Basic Food and Agri-businesses	US	4.0 %	10.0 %	28.6 %	8.3 %	10.9
	Eur	12.0	8.0	0.0	8.3	7.9
	Jap	12.0	4.0	7.1	0.0	5.9
	Other	0.0	4.0	0.0	0.0	2.0
Highly-processed Food	US	8.0	12.0	50.0	33.3	18.8
	Eur	36.0	26.0	0.0	25.0	24.8
	Jap	8.0	6.0	7.1	8.3	6.9
	Other	16.0	2.0	0.0	0.0	5.0
Beverages	US	0.0	2.0	0.0	16.8	3.0
	Eur	4.0	16.0	0.0	0.0	8.9
	Jap	0.0	4.0	7.1	0.0	3.0
	Other	0.0	6.0	0.0	0.0	3.0
	TOTAL	*100*	*100*	*100*	*100*	*100*
1986-1989						
Basic Food and Agri-businesses	US	13.6 %	8.0 %	20.0 %	7.1 %	10.9
	Eur	13.6	8.0	0.0	7.1	7.9
	Jap	13.6	4.0	6.7	0.0	5.9
	Other	4.5	2.0	0.0	0.0	2.0
Highly-processed Food	US	4.5	18.0	26.7	35.7	18.8
	Eur	31.8	28.0	6.7	21.4	24.8
	Jap	0.0	4.0	26.7	7.1	6.9
	Other	4.5	8.0	0.0	0.0	5.0
Beverages	US	0.0	0.0	6.7	14.3	3.0
	Eur	9.1	14.0	0.0	0.0	8.9
	Jap	0.0	2.0	6.7	7.1	3.0
	Other	4.5	4.0	0.0	0.0	3.0
	TOTAL	*100*	*100*	*100*	*100*	*100*

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	82	101	101
DF	33	33	33
Pearson Chi-square	51.49	55.99	45.75
P-value	0.0212	0.0075	0.0690

Table 6.3.10 - which classifies the firms by industry and country, on the one hand, and by number of patents, on the other - shows that a large share of heavy patentors (between 33% and 39% in each period) is persistently to be found among US manufacturers of highly-processed food. European processors of this type of food are also well represented (21% to 25%), although to a lesser extent; while data on non-patentors in the same table show that a surprisingly large share of non-patentors (31% to 37%) are European manufacturers of such highly-processed foods, even though that share declines over time (i.e. from the latter to the former percentage). This reduction, however, could be attributable to increased propensities to patent in the USA, e.g. through setting up more businesses in that country.

The combined effects of industry and country are interrelated with the average number of patents per year, according to the statistics displayed at the bottom of Table 6.3.10. The results of the chi-squared and G2 tests are statistically significant at under the 10% level. An alternative approach analyzing row rather than column totals and percentages shows clear differences in the patenting behaviour of European firms and their competitors, by industry (data not displayed here).

The number of patents is a useful indicator of sectoral patterns of innovation but does not provide an accurate measure of innovativeness at the firm level because it may be influenced by firm size. Therefore, many studies deflate the number of patents by sales, assets or employment to obtain a more reliable indicator of relative firm innovativeness (Branch, 1974). We shall focus on this interpretation in the following paragraphs.

6.3.5.2 Innovative intensity

a) Innovative intensity and Size

When patents are deflated by sales, innovative intensity reflects the number of patents per unit of output, in this case billion dollars of sales. We classify firms by three levels of innovative intensity, derived from a histogram: non-patentors, firms with fewer than 2.4 patents per billion-dollar sales per annum, and firms with more than 2.4 patents per billion-dollar sales per annum. Table 6.3.11 contains a cross-classification of firms into these levels of innovative intensity and the four levels of asset values adopted previously (in Table 6.3.5). Table 6.3.12 replaces the latter with the four levels of sales values also used above (in Table 6.3.6).

By reading across the columns, it can be seen that “non-intensive” firms, i.e. non-patentors and firms with fewer than 2.4 annual patents per billion-dollar sales, tend to be smaller in this sample. Conversely, “intensive” firms, i.e. firms with higher patenting rates, tend to be giant businesses. However the differences are not overwhelming, and the evidence does not support the hypothesis of interrelation between size and innovative intensity. The results of the Pearson chi-squared test (at the bottom of these Tables) are not statistically significant, except in 1977-81.

Table 6.3.11: Food and Drink Firms Classified According to Innovative Intensity and Assets (1977-81, 1982-85, 1986-89; percentages of column totals)*

Innovative Intensity	Non-patentor	Low-intensity	High-intensity	Total
1977 - 1981				
< US$ 1b	70.6 %	41.3 %	37.5 %	46.8 %
US$ 1.1 b - 2.0 b	17.6	30.4	37.5	29.1
US$ 2.1 b - 4.0 b	11.8	21.7	12.5	17.7
> US$ 4.0 b	0.0	6.5	12.5	6.3
1982 - 85				
< US$ 1b	58.3 %	39.0 %	35.7 %	43.3 %
US$ 1.1 b - 2.0 b	12.5	25.4	21.4	21.6
US$ 2.1 b - 4.0 b	25.0	20.3	7.1	19.6
> US$ 4.0 b	4.2	15.3	35.7	15.5
1986 - 89				
< US$ 1b	42.9 %	21.9 %	0.0 %	23.7 %
US$ 1.1 b - 2.0 b	23.8	21.9	33.3	23.7
US$ 2.1 b - 4.0 b	28.6	23.4	16.7	23.7
> US$ 4.0 b	4.8	32.8	50.0	28.9

* No of patents/sales x 1000; low intensity < 2.4 patents p.a.; high intensity > 2.4 p.a.

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	79	97	97
DF	6	6	6
Pearson Chi-square	6.88	10.19	13.63
P-value	0.3326	0.1170	0.0340

Table 6.3.12: Food and Drink Firms Classified According to Innovative Intensity and Sales (1977-81, 1982-85, 1986-89; percentages of column totals)

Innovative Intensity	Non-patentor	Low-intensity	High-intensity	Total
1977 - 1981				
< US$ 1.5 b	68.4 %	31.9 %	37.5 %	41.5 %
US$ 1.6 b - 3.6 b	5.3	51.1	25.0	35.4
US$ 3.7 b - 6.0 b	26.3	10.6	25.0	17.1
> US$ 6.0 b	0.0	6.4	12.5	6.1
1982 - 85				
< US$ 1.5 b	32.0 %	31.1 %	33.3 %	31.7 %
US$ 1.6 b - 3.6 b	32.0	37.7	33.3	35.6
US$ 3.7 b - 6.0 b	20.0	18.0	0.0	15.8
> US$ 6.0 b	16.0	13.1	33.3	16.8
1986 - 89				
< US$ 1.5 b	18.2	14.9	8.3	14.9
US$ 1.6 b - 3.6 b	50.0	34.3	33.3	37.9
US$ 3.7 b - 6.0 b	22.7	20.9	16.7	20.8
> US$ 6.0 b	9.1	29.9	41.7	26.7

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	79	97	97
DF	6	6	6
Pearson Chi-square	17.97	5.98	5.60
P-value	0.0063	0.4255	0.4695

b) Innovative intensity and Profitability

Table 6.3.13 classifies the firms by the three innovative levels and by the three levels of profit used previously in Table 6.3.7. The chi-squared statistic at the bottom of the table indicates that innovative intensity and rate of profit are unrelated (though results are nearly statistically significant at the 10% level in 1977-81). Innovative intensity is also unrelated to profitability above the norm, except in 1977-81 (Table 6.3.14).

c) Innovative intensity, Countries and Industries

An important question is whether the weaker position of European firms suggested by the analysis of patents is an effect of their having a smaller size than the US firms. We can return to the cross-tabulations of Table 6.3.10 as an approximation to the categories of innovative intensity used here. The situation regarding non-patentors has already been described. US manufacturers of highly-processed food and US manufacturers of basic food as well as agri-businesses stand out among the highly-intensive firms in 1977-81. However, the situation evolved. In 1986-89, the enterprises standing out among the intensive firms tend to be Japanese as well as US processors of highly-processed food. By contrast, European manufacturers of highly-processed food stand out among less-intensive firms. The Pearson chi-squared and the G2 tests based on the definitions of intensity used here show innovativeness is interrelated with industry/country, with the results being statistically significant at about the 10% level or less.

Examination of the row totals shows that firms have tended to concentrate in the intermediate stratum of "low intensity". This situation reflects both rapid increases in sales and relative stability of the average number of patents issued to firms throughout the period. This trend also shows up in European firms.

d) Sub-sectoral differences

a) Basic Food and Agri-businesses. The proportion of highly intensive firms falls while that of low-intensive firms remains rather stable and that of non-patentors drops among both US and European firms. Among Japanese firms, the shares of non-patentors and less-intensive firms remain stable but the proportion of highly-intensive firms rises. However this increase may simply reflect more patenting in the US, following greater business involvement of Japanese firms in this country at the end of the 1980s.

b) Highly-processed Food. The proportion of non-patentors and less-intensive firms rose while that of highly intensive firms fell among US firms. The share of non-patentors and highly-intensive firms decreased but that of low-intensive firms increased among European processors.

c) Beverages. By the end of the 1980s, European firms were not represented in the intensive group.

6.3.13: Food and Drink Firms Classified According to Innovative Intensity and Profit (1977-81, 1982-85, 1986-89; percentages of column totals)*

Innovative Intensity	Non-patentor	Low-intensity	High-intensity	Total
1977 - 1981				
10%	31.3 %	26.1 %	31.3 %	28.2 %
11% - 20%	43.8	67.4	68.8	62.8
> 20%	25.0	6.5	0.0	9.0
1982 - 85				
10%	43.5 %	32.2 %	30.8 %	34.7 %
11% - 20%	43.5	59.3	38.5	52.6
> 20%	13.0	8.5	30.8	12.6
1986 - 89				
10%	35.0 %	21.0 %	41.7 %	26.6 %
11% - 20%	45.0	48.4	16.7	43.6
> 20%	20.0	30.6	41.7	29.8

* Net Profit/own capital

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	78	95	94
DF	4	4	4
Pearson Chi-square	7.67	6.23	5.85
P-value	0.1044	0.1824	0.2105

Table 6.3.14: Food and Drink Firms Classified According to Innovative Intensity and Comparative Profitability (1977-81, 1982-85, 1986-89)*

Innovative Intensity	Non-patentor	Low-intensity	High-intensity	Total
1977 - 1981				
Below Average	75.0 %	60.9 %	37.5 %	59.0 %
Above Average	25.0	39.1	62.5	41.0
1982 - 85				
Below Average	60.9 %	54.2 %	30.8 %	52.6 %
Above Average	39.1	45.8	69.2	47.4
1986 - 89				
Below Average	70.0 %	59.7 %	58.3 %	61.7 %
Above Average	30.0	40.3	41.7	38.3

* Net profit/own capital of the firm (relative to sub-sector average)

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	78	95	94
DF	2	2	2
Pearson Chi-square	4.82	3.18	0.75
P-value	0.0900	0.2040	0.6880

Table 6.3.15: Cross-classification of Food and Drink Firms by Innovative Intensity, Industry and Home-Country (1977-81, 1982-85, 1986-89; percentages of column totals)*

Industry	Home Country	Non-patentor	Low-intensity	High-intensity	Total
1977-1981					
Basic Food and Agri-businesses	US	5.3 %	10.6 %	25.0 %	12.2 %
	Eur	5.3	8.5	12.5	8.5
	Jap	15.8	6.4	0.0	7.3
	Other	5.3	2.1	0.0	2.4
Highly-processed Food	US	0.0	25.5	31.3	20.7
	Eur	36.8	12.8	12.5	18.3
	Jap	0.0	2.1	18.8	4.9
	Other	15.8	2.1	0.0	4.9
Beverages	US	0.0	6.4	0.0	3.7
	Eur	10.5	12.8	0.0	9.8
	Jap	5.3	4.3	0.0	3.7
	Other	0.0	6.4	0.0	3.7
	TOTAL	*100*	*100*	*100*	*100*
1982-1985					
Basic Food and Agri-businesses	US	4.0 %	13.1 %	13.3 %	10.9 %
	Eur	12.0	6.6	6.7	7.9
	Jap	12.0	3.3	6.7	5.9
	Other	0.0	3.3	0.0	2.0
Highly-processed Food	US	8.0	23.0	20.0	18.8
	Eur	36.0	19.7	26.7	24.8
	Jap	8.0	3.3	20.0	6.9
	Other	16.0	1.6	0.0	5.0
Beverages	US	0.0	3.3	6.7	3.0
	Eur	4.0	13.1	0.0	8.9
	Jap	0.0	4.9	0.0	3.0
	Other	0.0	4.9	0.0	3.0
	TOTAL	*100*	*100*	*100*	*100*
1986-1989					
Basic Food and Agri-businesses	US	13.6 %	10.4 %	8.3 %	10.9 %
	Eur	13.6	6.0	8.3	7.9
	Jap	13.6	3.0	8.3	5.9
	Other	4.5	1.5	0.0	2.0
Highly-processed Food	US	4.5	22.4	25.0	18.8
	Eur	31.8	25.4	8.3	24.8
	Jap	0.0	4.5	33.3	6.9
	Other	4.5	6.0	0.0	5.0
Beverages	US	0.0	3.0	8.3	3.0
	Eur	9.1	10.4	0.0	8.9
	Jap	0.0	4.5	0.0	3.0
	Other	4.5	3.0	0.0	3.0
	TOTAL	*100*	*100*	*100*	*100*

* No of patents/sales x 1000; low intensity < 2.4 patents p.a.; high intensity > 2.4 p.a.

Significance levels:	**1977-81**	**1982-85**	**1986-89**
No. of observations	82	101	101
DF	22	22	22
Pearson Chi-square	38.97	31.58	30.70
P-value	0.0142	0.0848	0.1025

6.3.5.3 Home Country and Firm Size

Another way to minimize the home-country bias in international comparisons of innovativeness is to combine the home-country and the firm-size effects. Here, we compare the mean innovative intensity of nine groups: small US firms, small European firms, small Other country firms, medium US firms, medium European firms, medium Other country firms, large US firms, large European firms and large Other country firms (Other countries include Japan). Size levels are defined as follows: up to US$ 1.5b global sales (small firms); from US$ 1.5b to US$ 3.6b (medium-sized firms); and greater than US$ 3.6b (large firms). The tabulations are set out in Table 6.3.15, measured as percentages of the column totals for each sub-period.

The null hypothesis to be tested with an analysis of variance (ANOVA) is that the mean intensity is the same for the nine groups. The results are shown separately for each sub-period in the panels of Table 6.3.16.

a) In 1977-81, US firms exhibit higher average intensity for the three size levels (panel A). This means that large US firms show higher innovative intensity than large European firms, medium US firms higher than medium European firms, and so on. Moreover, medium and even small US firms show higher average intensity than large European firms. From this Table it is not possible to establish how far this difference is due to the USA being the country of patenting, but in our view it also suggests a greater degree of innovativeness among the US firms (compare also with the results on Relative Technological Advantage computed elsewhere in this Report). The Two-way ANOVA (below the panel) reveals significant differences in innovativeness among the means of the country groups at under the 5% level, but not among the size groups. This lack of significant interaction indicates that differences between countries are about the same at each size level. The greatest differences in innovative intensity are between, on the one hand, large US firms and, on the other, medium and small European firms. This situation is unfavourable to these medium and small European firms because they will be encountering affiliates of the large, highly innovative US firms in their own home markets.

b) In 1982-85, the interpretation of results is similar (panel B). However, the gap between large US firms and medium European firms has tended to close.

c) In 1986-89, large and medium US firms still exhibit higher average intensity than similar firms from other countries (panel C). Small European firms could have become more intensive than small US and Other country firms. The possibility cannot be excluded that the cause was an increase in foreign patenting of small European firms, following greater involvement in the USA, rather than any domestic increase in innovativeness. The ANOVA test reveals significant differences due to country and to the interaction of country as well as size. Differences in size, however, remain statistically insignificant.

Table 6.3.16: Two-way Analysis of Variance of Average Innovative Intensity grouped by type of firm*

A) 1977-81

Summary Statistics:		*Mean*	*Std. Dev.*	*S.E.Mean*	*Maximum*	*Minimum*	*Cases*
Small:	US	.128	.106	.037	.380	.058	8
	Europe	.090	.081	.022	.364	.058	14
	Other	.115	.068	.020	.282	.058	11
Medium:	US	.115	.071	.020	.319	.060	12
	Europe	.085	.033	.011	.169	.061	9
	Other	.099	.071	.025	.266	.058	8
Large:	US	.162	.070	.022	.351	.109	10
	Europe	.094	.049	.020	.182	.058	6
	Other	.058	.000	.000	.058	.058	3
All		.109	.072**	.008	.380	.058	81

* Analysed in logarithmic form
**Robust S.D. = 0.063

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROBABILITY
ANALYSIS OF VARIANCE:					
SIZE	0.0019	2	0.0009	0.19	0.8302
COUNTRY	0.0348	2	0.0174	3.44	0.0374
INTERACTION	0.0158	4	0.0040	0.78	0.5407
ERROR	0.3640	72	0.0051		
BROWN-FORSYTHE TEST*:					
SIZE		2, 45		0.20	0.8202
COUNTRY		2, 44		3.88	0.0280
INTERACTION		4, 43		1.34	0.2716
LEVENE TEST:**					
SIZE		2, 72		1.55	0.2195
COUNTRY		2, 72		1.10	0.3373
INTERACTION		4, 72		0.55	0.6980

* For equality of means; variances not assumed to be equal
** For equality of variances

B) 1982-85

Summary Statistics:		*Mean*	*Std. Dev.*	*S.E.Mean*	*Maximum*	*Minimum*	*Cases*
Small:	US	.037	.029	.012	.069	.000	6
	Europe	.027	.035	.008	.118	.000	18
	Other	.074	.090	.032	.234	.000	8
Medium:	US	.050	.067	.024	.181	.000	8
	Europe	.034	.075	.018	.292	.000	17
	Other	.049	.079	.024	.279	.000	11
Large:	US	.075	.082	.019	.291	.000	19
	Europe	.035	.056	.021	.138	.000	7
	Other	.001	.002	.001	.005	.000	7
All		.044	.067**	.007	.292	.000	101

* Analysed in logarithmic form
**Robust S.D. = 0.059

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROBABILITY
ANALYSIS OF VARIANCE:**					

SIZE	0.0024	2	0.0012	0.79	0.4594
COUNTRY	0.0077	2	0.0038	2.56	0.0853
INTERACTION	0.0092	4	0.0023	1.53	0.2055
ERROR	0.0926	62	0.0015		
WELCH TEST*:		8, 19		6.53	0.0004
BROWN-FORSYTHE TEST*:					
SIZE		2, 15		0.52	0.6035
COUNTRY		2, 14		1.86	0.1917
INTERACTION		4, 15		1.31	0.3117

* For equality of means; variances not assumed to be equal
** With 15% trimming

C) 1986-89

Summary Statistics:		*Mean*	*Std. Dev.*	*S.E.Mean*	*Maximum*	*Minimum*	*Cases*
Small:	US	.013	.022	.013	.038	.000	3
	Europe	.015	.016	.005	.055	.000	10
	Other	.112	.145	.102	.215	.010	2
Medium:	US	.021	.018	.007	.044	.000	8
	Europe	.015	.020	.019	.250	.000	16
	Other	.050	.072	.024	.279	.000	14
Large:	US	.060	.055	.012	.231	.000	22
	Europe	.033	.053	.013	.183	.000	16
	Other	.021	.029	.009	.088	.000	10
All		.035	.051**	.005	.250	.000	101

* Analysed in logarithmic form
**Robust S.D. = 0.045

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROBABILITY
ANALYSIS OF VARIANCE:**					
SIZE	0.0030	2	0.0015	1.26	0.2918
COUNTRY	0.0110	2	0.0055	4.62	0.0135
INTERACTION	0.0162	4	0.0041	3.41	0.0139
ERROR	0.0734	62	0.0012		
WELCH TEST*:		8, 17		1.25	0.3899

* For equality of means; variances not assumed to be equal
** With 15% trimming

6.3.5.4 Conclusions

1. The most important sources for total numbers of patented innovations are very large, profitable firms, which obtain above-average gains.

2. Innovative intensity is little related to size, profits or profitability above the norm. By contrast, it is significantly related to the industry and the home country in which the firm is based. Firms from European countries have tended to show some improvement over time but may still be lagging, particularly in certain subsectors.

6.3.6 Innovative intensity and Profitability

The preceding Section suggested that innovativeness and profitability were unrelated in this industry. This Section further explores the relationship of both variables. In doing so, it demonstrates that this apparent lack of association conceals, in fact, different roles for innovation in different types of firms within this industry.

6.3.6.1 The Framework and the Hypotheses

Salais and Storper (1992), among others, have called our attention to the differences in industrial structures and performance among nations revealed by studies of comparative industrialisation. Such authors believe that countries and firms do not converge necessarily towards the same level of profitability; neither do they use the same combination of products, organization and resources - such as fixed capital, circulating capital, credit and labour - to obtain high profit. By contrast with orthodox economic theory, in these authors' views diversity would not necessarily be a failure to adopt best practices. In short, different rationalities for profitability could be observed within the same industry and even among countries.

In some cases, divergent paths to profitability are associated with different home countries. Geroski and Jacquemin (1988) found country-wide factors were more discriminating than firm- or industry-specific factors in a study on the persistence of profit in three European countries. Coriat (1990), who compares the US and Germany, concludes that paths to the achievement of profit are different in the two countries.

Other authors focus on the different paths to profitability used by groups of firms, independently of their home country. Our approach in this Chapter of the Report is drawn partly from that of Porter (1980), in which industries are formed by "strategic groups" following the same or a similar strategy. Differences in strategy may imply differences in product mix, scale, technology, capital requirements and other sources of entry barriers. Groups are not equivalent to market segment. Firms in different groups often show differences in profitability but not always. One of Porter's hypotheses is that firms which are good at some types of strategy are often less efficient at others: firms achieving a low-cost position, for instance, are likely to be less efficient at technological development.

Therefore, the first idea we develop in this Section is that there are a multiplicity of profit maximizing strategies in the food-processing industry. We shall also study whether paths to profitability are influenced by home countries or by the presence of strategic groups within this industry (or by both). As shown in the last Section, highly profitable firms may or may not be great patentors of innovations. Therefore we shall test the hypothesis that innovativeness plays divergent roles in different strategic groups. In other words, we assume two groups may eventually obtain similar levels of profit, one via innovativeness and the other via alternative strategies: While the rate of profit might be similar, the method used to achieve it might not be.

The test of these hypotheses follows three steps:

a) A linear regression between profitability (as the dependent variable) and innovativeness as well as other independent variables, by home-country;

b) a cluster analysis identifying different strategic groups in this industry;

c) a cross-tabulation of strategic groups with a variable indicating the home country of the firm and a series of ANOVA tests which establish the extent of differences in profitability among groups.

6.3.6.2 The Regression Analysis

We shall test here whether the same set of variables, including innovativeness, explain profit in firms based in different home countries. We shall also test the hypothesis that the sign and level of association of innovativeness as well as profitability are distinct in firms based in different home countries.

We use a least-squares linear regression equation between the dependent variable, profit, and the following independent variables: assets, capital structure or gearing, and innovative intensity. The equality of regression lines across groups of countries is tested for, i.e. whether the regression equations for different countries are the same.

Although a number of authors utilise a lagged variable to measure the impact of innovativeness on profit (Branch, 1974; Grabowski, 1968), others measure both variables in the same year (Himmelberg and Petersen, 1994; Acs and Isberg, 1991b). We have therefore used both measures of innovativeness. A set of equations analyses the effects of innovative intensity in period *t-1* on profit in period *t* (Table 6.3.18). Another studies the influence of innovative intensity in period *t* on profit in period *t* (Table 6.3.19).

The distribution of the variables is log-normal. That of the residuals of the technological variable is normal and does not suggest a significant non-linear association with profit. There is no evidence of multicollinearity among the variables.

The general results seem to confirm a lack of association between innovativeness and profitability (Table 6.3.17). The analysis by home country, however, shows a different picture. For the final years 1986-89, according to the F statistic and the multiple R2 (bottom of Tables 6.3.18 and 6.3.19), the model explains a significant share of the variance of the profitability of US and, especially, Other country firms for both specifications of the technological variable. However, the model fits the data of European firms poorly. This means the combined effects of size, capital structure and innovativeness are insufficient to explain the variance of profit in European firms. This conclusion implies that profit is not explained by the same set of variables for firms based in different home countries. As suggested by Lecraw (1983), multinationals from different home countries operate abroad based on different competitive advantages they have developed as a response to the availability of funding, technology and so on in their home market.

Table 6.3.17: Regression Results for Profit Equations, All Firms, 1982-85 and 1986-89

Variable	1982-85		1986-89	
	Lagged Innovation Intensity*	Non-lagged Innovation Intensity	Lagged Innovation Intensity**	Non-lagged Innovation Intensity
Intercept	0.1032	0.0921	0.0358	0.0242
Log Assets	0.0025 (0.37)	0.0036 (0.54)	0.0115 (1.11)	0.0149 (0.16)
Log Gearing	-0.0544 (-2.83)	-0.0360 (-1.86)	0.0307 (1.15)	0.0295 (0.11)
Log Innovative Intensity	0.0471 (1.66)	0.0393 (0.93)	0.0281 (0.44)	-0.0339 (-0.05)
No. of Cases	78	93	94	94
F-Ratio	4.27	2.04	1.08	1.07
Multiple R^2	0.148	0.064	0.035	0.035

(t statistics below coefficients)
* i.e. for 1977-81
** i.e. for 1982-85

Table 6.3.18: Regression Results for Profit Equations, by Country (1982-85 and 1986-89), with Lagged Variable for Innovative Intensity

VARIABLE	1982-85			1986-89		
	US	Europe	Other	US	Europe	Other
Intercept	0.1109	0.2970	0.0481	-0.0253	0.1707	-0.0005
Log Assets	0.0004 (-0.04)	-0.0396** (-2.58)	0.0176* (1.95)	0.0098 (0.73)	-0.0174 (-0.69)	0.0283** (2.80)
Log Gearing	-0.0457 (-0.92)	-0.0970** (-3.16)	-0.0644** (-4.35)	0.1851** (4.22)	0.0084 (0.14)	-0.0716** (-4.91)
Log Inn. Intensity (non lagged)	0.0720* (1.92)	0.3860** (2.45)	-0.0583 (-1.52)	-0.0092 (-0.12)	0.1840 (0.53)	-0.1164** (-2.68)
No. of Cases	48	10	20	50	19	25
F Statistics	1.42	4.28*	7.79**	6.98*	0.21	9.21**
Multiple R^2	0.088	0.681	0.594	0.313	0.040	0.568

(t statistics below coefficients)
* Significant at between 5% and 10% levels
** Significant at 5% level or less.

Table 6.3.19: Regression Results for Profit Equations, by Country (1982-85 and 1986-89), with Non-Lagged Variable for Innovative Intensity

VARIABLE	1982-85			1986-89		
	US	Europe	Other	US	Europe	Other
Intercept	0.0807	0.2043	0.0479	-0.0314	0.2060	-0.0020
Log Assets	0.0039 (0.39)	-0.0227 (-0.94)	0.0173** (2.23)	0.0114 (0.87)	-0.0256 (-0.94)	0.0280** (2.65)
Log Gearing	-0.0174 (-0.37)	-0.0489 (-1.05)	-0.0665** (-4.71)	0.1853** (4.37)	0.0025 (0.04)	-0.0679** (-3.75)
Log Inn. Intensity (non lagged)	0.0997* (1.73)	0.2266 (0.70)	-0.0673** (-2.06)	-0.0412 (-0.37)	0.3759 (0.85)	-0.1109** (-2.19)
No. of Cases	51	19	23	50	19	25
F Statistics	1.58	0.55	8.65*	7.04**	0.36	7.85**
Multiple R^2	0.092	0.099	0.577	0.315	0.067	0.529

(t statistics below coefficients)

* Significant at between 5% and 10% levels

** Significant at 5% level or less.

In both US and Other country firms the sign and significance of the technological coefficient remain unchanged when we modify the specification of the technological variable (lagged or non-lagged). In US firms, the sign of the technological coefficient is positive and significant during the 1982-85 crisis; however, it is negative, although not statistically significant, over the 1986-89 recovery period. The result for the second period would seem to contradict the theory put forward in Section 6.3.2 above, i.e. of a positive association between innovativeness and profit. It is consistent, however, with the notion of a trade-off between innovativeness and profit developed by Kamien and Schwartz (1975) as well as by Branch (1974). A possible explanation is that R&D became less crucial to US firms owing to the anticipation of high profits over 1986-89. Directors would be less prone to spend money on R&D when the firm is already performing well (or success is predicted). In addition, high profits usually coincide with periods of heavy demand during which engineers and scientists are likely to be shifted from the firm laboratories to the industrial plant, a situation tending to reduce innovations by unit value of sales (Branch, 1974). The significant coefficient for gearing in the US firms for this period suggest the primacy of financial determinants of profitability.

The negative and significant sign of the technological coefficient in Other country firms also confirms these authors' point of view. According to them, when the firm predicts lower performance than its competitors, it is likely to embark on R&D projects generating new products and processes (this also constitutes the assumption underlying "search" behaviour in the non-neoclassical model of Nelson and Winter, 1974). As seen in Section 6.3.3, Other country firms - especially Japanese ones - actually got lower returns than their competitors over the period studied here.

Finally, in European firms, the sign of the technological coefficient is positive but insignificant. Geroski *et al.* (1993) also found a negative association between innovation and profit in British food-processing firms.

6.3.6.3 The Cluster Analysis

Even though the regression analysis gives some interesting insights into divergences between firms based in different home countries, it does not supply a general explanation for the association of innovativeness and profit in this industry.

We shall now attempt to establish a more global explanation based on Porter's strategic-group construct. The previous discussion suggested that the relationship between innovativeness and profit depended on a number of trade-offs and interrelated factors. Therefore it is necessary to study the mutual association among a great number of structural characteristics and strategies. The underlying premise is that firms are not homogeneous within industries (Bush and Sinclair, 1991). We assume, by contrast, that each cluster would be a coherent combination of technological and financial strategies as well as practices of resource use (Salais and Storper, 1992). These models have, in our view, implications for the pattern of competition in the food-processing industry at large.

To study the underlying structure of a great mass of data, including profit and innovativeness data, we use the K-means cluster analysis, which is an interdependent multivariate method that classifies each firm into the cluster whose centre is closest in Euclidean distance to the firm (the centre of the cluster is defined as the mean of the cases in the cluster). This technique groups cases which are very similar in a variety of characteristics. Since the variables are measured in different units, we use the variance to standardize our data and give equal weight to each variable.
The model comprises both economic and technological variables: assets*, profits, margins*, rotation*, gearing*, number of patents*, innovative intensity, food, biotechnology, diversification, and experience (starred variables are measured as their logarithms, for variables that are lognormally distributed).

These variables - which have been defined in Table 6.3.2 - denote strategic options regarding the type of financial resources, the type and level of technology, the use of production factors, and so on. The reasons for selecting this set are the following:
Sales Large size may bring economies of scale in production, R&D and distribution. Scale is an important element to building entry or mobility barriers and a determinant of bargaining power of the firm *vis-à-vis* suppliers as well as retailers (Porter, 1980).
Margins Low margins suggest low sales prices or high costs (or both). It is a decomposition of the profit rate so it helps to describe how profits arise.
Profits This is a measure of the rate of return on investment.
Gearing This shows the leverage of the firm. It provides a measure of the funds contributed by creditors relative to investors. A high level of gearing increases risk and the profitability-versus-risk trade-off is a crucial consideration for the firm. Moreover, low gearing increases the value of the firm though, on the contrary, high gearing raises the cost of equity. According to the signalling theory, capital structure may be used by managers to send signals to the public about the future performance of the firm, signs that cannot be imitated by unsuccessful firms because such firms do not have enough cash flow to back this strategy (Copeland and Weston, 1992). In general, managers prefer internal funds supplemented by loans because this structure gives the firm more certainty and independence (Bowman and Asch, 1987).

<u>*Rotation of Capital*</u> The sales to capital ratio is a measure of both the level of firm activity and efficient utilization of own capital. A low rate means the firm is not generating a sufficient volume of business, given its level of investment.
<u>*Capital Intensity*</u> This measures the use of capital relative to labour.
<u>*Number of patents*</u> A great number of patents suggest the firm owns important intangible assets.
<u>*Biotechnology*</u>, <u>*food*</u> and <u>*diversification*</u> These variables point to capabilities and specialization options in the technological field. In addition, biotechnology indicates expertise in technologically advanced products, as a generic technology applicable to numerous fields within food-processing, animal and plant genetics; this characteristic may promote product diversification and vertical integration. Diversification may reduce dependence on suppliers of technology.
<u>*Experience*</u> One school of thought sees knowledge as accumulative. In this light, early patentors would show technological advantages *vis-à-vis* less experienced firms. Another perceives technological change as a basically discontinuous process. This perspective would produce a "dinosaur" syndrome among early patentors, who may be frozen into old technology, putting a brake on production of current technology in these firms.

We obtain three clusters which are shown in Tables 6.3.20 to 6.3.22. As indicated by the F-ratios, the technological variables, with the exception of biotechnology, are rather important determinants of cluster formation. The cluster profiles are easier to assess by first ordering the variables according to their F-ratio. This provides an insight into how strategic groups compete in food-processing.

The strategic groups with the highest levels of innovativeness persistently display the highest average profit rates in 1977-81 (column 1 of Table 6.3.20), 1982-85 (column 2 of Table 6.3.21) and 1986-89 (column 2 of Table 6.3.22). Throughout 1977-81, and especially the 1982-85 crisis, these groups moreover show the lowest standard deviation of profits, a feature often interpreted as an indicator of lower risk (Telser, 1988). More importantly, these groups are the only ones to display profits above the norm. Innovative firms tend to display larger sizes, significant intangible assets and higher degrees of diversification into non-food technologies.

Data on the least innovative groups are shown in the third columns of each of these Tables. These firms are persistently the most specialized in food technology, the least diversified into non-food technology and the least experienced. They consistently exhibit the lowest rates of profits and margins. They demonstrate efficient use of capital, as evidenced by the highest rates of rotation, and great potential to secure external funding. Capital intensity, on the contrary, is rather low.

Table 6.3.20: Cluster Analysis, 1977-81

Variables	Cluster 1*	Cluster 2	Cluster 3	Grand Mean	F-Ratio	P-value
Economic variables						
Log Sales	4.5780	4.2537	4.1641	4.3002	10.92	0.000
	(0.3378)	(0.3084)	(0.3286)			
Profit	0.1522	0.1205	0.1325	0.1343	1.46	0.238
	(0.0385)	(0.0935)	(0.0445)			
Log Margin	0.0172	0.0058	0.0182	0.0140	33.02	0.000
	(0.0007)	(0.0033)	(0.0074)			
Log Rotation	0.6067	0.9580	0.4895	0.6613	49.25	0.000
	(0.1392)	(0.1874)	(0.1796)			
Log Capital Intensity	1.3416	1.3454	1.4172	1.3760	0.74	0.483
	(0.2730)	(0.2582)	(0.2634)			
Log Gearing	0.4707	0.6317	0.4336	0.5003	24.36	0.000
	(0.0616)	(0.1521)	(0.0911)			
Technological variables						
Log no of Patents	1.1783	0.2258	0.2252	0.4725	122.36	0.000
	(0.3141	(0.2314)	(0.1898)			
Innovative intensity	0.4862	0.0688	0.0863	0.1843	19.68	0.000
	(0.4231)	(0.0984)	(0.1990)			
Biotechnology	0.0678	0.0728	0.0320	0.0550	0.74	0.481
	(0.1228)	(0.1407)	(0.1069)			
Food	0.2893	0.3724	0.2752	0.3061	0.59	0.555
	(0.2239)	(0.3739)	(0.2917)			
Diversification	5.6548	0.6885	0.7147	1.9870	98.54	0.000
	(2.4503)	(0.7946)	(0.6759)			
Experience	44.1376	29.0085	33.9209	34.9928	2.33	0.104
	(16.2654)	(24.4460)	(27.7622)			
N	21	26	34			

Notes: Figures in Clusters columns represent Cluster Means, with Standard Deviations below in parentheses
* = Most innovative-intense cluster.

Table 6.3.21: Cluster Analysis, 1982-85

Variables	Cluster 1	Cluster 2*	Cluster 3	Grand Mean	F-Ratio	P-value
Economic variables						
Log Sales	4.3437	4.8121	4.2329	4.3815	20.83	0.000
	(0.3196)	(0.3682)	(0.3033)			
Log Profit	0.0868	0.1025	0.0857	0.0893	2.97	0.056
	(0.0227)	(0.0193)	(0.0300)			
Log Margin	0.0284	0.0298	0.0204	0.0252	4.50	0.014
	(0.0118)	(0.0113)	(0.0163)			
Log Rotation	0.4663	0.6255	0.9764	0.7167	53.89	0.000
	(0.1793)	(0.2049)	(0.2592)			
Log Capital Intensity	1.6247	1.5207	1.4400	1.5262	3.04	0.053
	(0.3174)	(0.2933)	(0.3472)			
Log Gearing	0.3322	0.4129	0.5465	0.4377	22.41	0.000
	(0.0907)	(0.0868)	(0.1876)			
Technological variables						
Log no of Patents	0.3501	1.3043	0.1308	0.4298	124.66	0.000
	(0.3045)	(0.3909)	(0.1309)			
Innovative intensity	0.0875	0.4240	0.0301	0.1239	43.28	0.000
	(0.1109)	(0.3213)	(0.0369)			
Biotechnology	0.0628	0.0501	0.0127	0.0420	1.59	0.212
	(0.1422)	(0.1105)	(0.0464)			
Food	0.2817	0.2169	0.6334	0.3913	10.66	0.000
	(0.3203)	(0.1648)	(0.4397)			
Diversification	1.1500	6.8148	0.3512	1.8342	159.73	0.000
	(1.1263)	(2.5848)	(0.3907)			
Experience	37.8090	38.4756	24.9255	32.5179	3.51	0.034
	(28.7795)	(12.9068)	(23.5175)			
N	40	18	42			

Notes: Figures in Clusters columns represent Cluster Means, with Standard Deviations below in parentheses
* = Most innovative-intense cluster.

Table 6.3.22: Cluster Analysis, 1986-89

Variables	Cluster 1	Cluster 2*	Cluster 3	Grand Mean	F-Ratio	P-value
Economic variables						
Log Sales	4.5655	4.8925	4.3891	4.5609	16.68	0.000
	(0.2954)	(0.3684)	(0.2731)			
Log Profit	0.9664	0.1011	0.0742	0.0897	9.26	0.000
	(0.0217)	(0.0295)	(0.0258)			
Log Margin	0.0245	0.0233	0.0089	0.0188	23.24	0.000
	(0.0120)	(0.0123)	(0.0067)			
Log Rotation	0.7144	0.7263	1.0181	0.8272	36.93	0.000
	(0.1571)	(0.1117)	(0.1931)			
Log Capital Intensity	1.7251	1.8900	1.6685	1.7336	2.54	0.085
	(0.3379)	(0.3534)	(0.3209)			
Log Gearing	0.4233	0.4997	0.6184	0.5079	15.66	0.000
	(0.0995)	(0.1127)	(0.2156)			
Technological variables						
Log no of Patents	0.3772	1.3561	0.1934	0.4872	105.33	0.000
	(0.2951)	(0.3804)	(0.2115)			
Innovative intensity	0.0522	0.3261	0.0316	0.0941	59.67	0.000
	(0.585)	(0.2065)	(0.0504)			
Biotechnology	0.0812	0.0474	0.0949	0.0777	0.29	0.750
	(0.2169)	(0.0735)	(0.2444)			
Food	0.3298	0.2188	0.4564	0.3430	2.54	0.086
	(0.3431)	(0.1803)	(0.4212)			
Diversification	1.2283	6.4583	0.6157	1.9492	123.71	0.000
	(1.0933)	(2.4449)	(0.8026)			
Experience	43.8515	30.0083	19.2908	32.5179	12.03	0.000
	(24.8921)	(16.8095)	(22.0280)			
N	46	18	36			

Notes: Figures in Clusters columns represent Cluster Means, with Standard Deviations below in parentheses
* = Most innovative-intense cluster.

6.3.6.4 The Analysis of Variance

The results of a One-way ANOVA test indicate divergences in comparative profitability are statistically significant at under the 10% level among the three strategic groups in each period (Table 6.3.23), with the sharpest differences being recorded in the final sub-period (1986-89). The results are robust to changes in the specification of the variable: similar results are obtained when we calculate the ANOVA for the logarithm of profits (Table 6.3.24).

Where are profit differences? A Tukey-Cramer test indicates that the mean groups differ significantly ($p < 0.005$) in 1977-81 and 1982-85. In 1986-89, the least innovative group differs significantly ($p < 0.001$) from the other two groups; though the latter two do not do so by themselves. One-way ANOVA in Table 6.3.23, testing the null hypothesis that comparative profits (i.e. profits higher or lower than average in the sub-sector) are similar in all groups, clarifies this question: only the most innovative group obtains profits above the norm. Although, in absolute terms, the performance of the other group is rather good, profits are slightly below the average of the sub-sectors in which the firms in this group compete.

Table 6.3.23: ANOVA of Comparative Profitability grouped by Cluster*

Summary Statistics:	*Mean*	*Std. Dev.*	*Robust SD*	*S.E.Mean*	*Maximum*	*Minimum*	*Cases*
A) 1977-81							
Cluster 1**	.018	.038		.008	.076	-.064	21
Cluster 2	-.014	.093		.019	.175	-.235	23
Cluster 3	-.002	.045		.008	.113	-.106	34
All	.000	.062	.058	.007	.175	-.235	78
B) 1982-85							
Cluster 1	-.009	.065		.011	.244	-.227	36
Cluster 2**	.036	.055		.013	.128	-.082	18
Cluster 3	-.008	.084		.013	.303	-.216	41
All	-.000	.074	.065	.008	.303	-.227	95
C) 1986-89							
Cluster 1	-.003	.064		.010	.165	-.140	43
Cluster 2**	.010	.087		.022	.210	-.130	16
Cluster 3	-.006	.071		.013	.107	-.249	30
All	-.022	.077	.077	.008	.210	-.249	89

* Net profit/own capital of the firm minus sub-sector average
** Most innovative cluster

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROBABILITY
ANALYSIS OF VARIANCE:					
1977-81++					
CLUSTER	0.0125	2	0.0063	2.55	0.0880
ERROR	0.1268	52	0.0025		
1982-85					
CLUSTER	0.0296	2	0.0148	2.82	0.0650
ERROR	0.4835	92	0.0053		
1986-89					
CLUSTER	0.0907	2	0.0453	8.94	0.0003
ERROR	0.4358	86	0.0051		
WELCH TEST*:					
1977-81		2, 28		3.11	0.0601
1982-85		2, 52		4.27	0.0192
1986-89		2, 37		8.54	0.0009
BROWN-FORSYTHE TEST*:					
1977-81		2, 29		2.33	0.1154
1982-85		2, 87		3.25	0.0434
1986-89		2, 44		7.69	0.0014
LEVENE TEST:**					
1982-85		2, 92		1.47	0.2363
1986-89		2, 86		0.75	0.2363

++ With 15% trimming
* For equality of means; variances not assumed to be equal
** For equality of variances

Table 6.3.24: ANOVA of Profit grouped by Cluster*

Summary Statistics:	*Mean*	*Std. Dev.*	*Robust SD*	*S.E.Mean*	*Maximum*	*Minimum*	*Cases*
A) 1977-81							
Cluster 1**	.152	.039		.008	.212	.070	21
Cluster 2	.121	.094		.020	.310	-.100	23
Cluster 3	.133	.045		.008	.248	.029	34
All	.134	.062	.058	.007	.310	-.100	78
B) 1982-85							
Cluster 1	.087	.023		.004	.164	.003	36
Cluster 2**	.103	.019		.005	.134	.062	18
Cluster 3	.086	.030		.005	.187	.000	41
All	.089	.026	.023	.003	.187	.000	95
C) 1986-89							
Cluster 1	.096	.022		.003	.150	.049	43
Cluster 2**	.101	.029		.007	.167	.053	16
Cluster 3	.074	.026		.005	.130	.000	30
All	.090	.027	.027	.003	.167	.000	89

* Log of profit
** Most innovative cluster

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROBABILITY
ANALYSIS OF VARIANCE:					
1977-81++					
CLUSTER	0.0124	2	0.0062	2.52	0.0907
ERROR	0.1272	52	0.0025		
1982-85					
CLUSTER	0.0039	2	0.0020	2.97	0.0561
ERROR	0.0604	92	0.0007		
1986-89					
CLUSTER	0.0113	2	0.0056	9.26	0.0002
ERROR	0.0523	86	0.0006		
WELCH TEST*:					
1977-81		2, 28		2.97	0.0678
1982-85		2, 52		4.39	0.0173
1986-89		2, 37		8.45	0.0009
BROWN-FORSYTHE TEST*:					
1977-81		2, 30		2.29	0.1184
1982-85		2, 87		3.34	0.0365
1986-89		2, 47		8.04	0.0010
LEVENE TEST:**					
1982-85		2, 92		1.53	0.2214
1986-89		2, 86		0.69	0.5052

++ With 15% trimming
* For equality of means; variances not assumed to be equal
** For equality of variances

It seems that its technological background helps this innovative group to make substantial enough profits. This result would confirm Geroski *et al.* (1993) in that the benefits of innovation seem to be permanent. Failure to generate current technology, however, hampers this group's potential for extraordinary gains. This half-way position regarding profit concurs somewhat with both those who believe old technology generates a "dinosaur" syndrome (Dosi, 1990) and those who think technology has long-run positive, indirect effects (Geroski *et al.*, 1993). This group actually performs better than that which is both weakly innovative and technologically inexperienced (columns 1 and 3 of Table 6.3.24).

The comparison of the two higher-profit groups (with only the most innovative of them achieving extraordinary gains) illustrates how firms use different types of resources and divergent technological competencies to do well (columns 1 and 2 of Table 6.3.22). The most innovative group probably produces standard products with important economies of scale and low shares of labour in value-added. This interpretation is suggested by high level of rotation (which is facilitated by production of a few generic items), considerable capital per worker and smaller margins (by comparison with the other group). The other group (column 1 of Table 6.3.22) is likely to produce speciality products necessitating the use of skilled labour. The range of products is probably wide, and thus routinization of production is rather difficult; margins are substantial but the use of capital is less efficient, probably owing to the nature of the business.

A cross-tabulation of the clusters against a variable indicating the home country of the firm discloses that only 10%-12% of the European companies in our sample appear in the most innovative clusters. On the other hand, European firms are doing well, as was shown in Section 6.3.4. This result, together with insignificant association between innovativeness and profit, is rather enigmatic. A possible cause for good performance is that large European firms balance their low levels of internal innovation with exceptional absorption of external innovation. Previous research suggests, in fact, that innovativeness of national food-processing industries, i.e. the ratio of the number of foreign patents issued to firms at the two-digit industry level, their suppliers and public centres of research to the value-added of each industry, is noteworthy in the EU. Moreover, the positive effect of these spillovers of knowledge on the performance of large food manufacturing firms has been proved elsewhere (Rama, 1994).

On the other hand, the bulk of Japanese firms (50%-62%) compete with the lowest innovative levels, the lowest profits and the highest gearing (although Ajinomoto and others are highly innovative). These firms are well placed to attract external finance because they are often part of large Japanese industrial-financial groups. Abundant loans help them to finance development and counterbalance moderate innovativeness as well as technological inexperience. As indicated in Section 6.3.4, financial considerations have been crucial in this industry. Yet this is probably a transitory strategy in the expansion of Japanese food-processing firms. As seen in Sections 6.3.4 and 6.3.5, a portion of these firms is becoming highly innovative. The regression results suggested, moreover, that this strategy is a response to the low profits earned on the part of these firms.

The bulk of firms in innovative, highly profitable clusters is made up of: the world's largest firms (Nestlé and Unilever), the largest producers of soft-drinks (Coca-Cola and Pepsico) and the largest US grain-processors (Ralston Purina, Quaker Oats, etc.). After

1982, however, a number of the latter firms have shifted to other types of strategy. Coversely, after this date, some large conglomerates (RJR Nabisco, Philip Morris, etc.) have adopted this model to operate in the food-manufacturing market.

6.3.6.5 Conclusions from Hypothesis Testing

The empirical tests supported our hypotheses to some extent. Paths to profitability are certainly influenced by country factors. In addition, the association of innovativeness and profit varies according to differences in home countries. While the association inclines to be positive in European firms, it is negative in firms based in new source countries. The latter try to balance their expected low profits with increases in innovativeness. In US firms, the relationship changes throughout the period, tending to be negative when high profits are anticipated.

Even if we identified several strategic groups within this industry, we proved only part of our hypothesis regarding different profit-maximizing strategies. Although it is true that two of these groups achieved similar absolute profit rates with divergent levels of innovativeness, only the most innovative made profits above the norm. The other group is not a good example of low innovativeness: as it is an important early patentor, its good performance could be, in part, a result of earlier experience even though firms in this group are unable to produce current technology to similar extents. Weakly innovative and technologically inexperienced groups are actually the least profitable.

6.3.7 Conclusions

1. In terms of the number of patents, innovation tends to be produced by giant, highly profitable firms with earnings above the norm. This implies that national food-processing industries formed by these types of enterprises - rather than by smaller, less successful concerns - are likely to lead world R&D in this field, to signal the direction of technological search and to have substantial influence upon the technical interface between this industry and its suppliers. This is an important consideration for home countries where firms are lesser patentors, because followers are likely to imitate innovation produced in the world's leading centres for food-processing technology; this technology, however, risks being less adaptable to conditions in their home countries in terms of natural resources and so on. This strategy therefore risks causing increases in imports of agricultural products, equipment, etc., and hence minimizing the beneficial effects of food processors' demand on the rest of the national food-chain. In this industry, there is some indication that US firms producing highly-processed food could play a significant role as technological leaders.

2. Heavy patentors tend to be profitable firms but the reverse is not always true. This result suggests that innovativeness is not the sole path to profit in food processing and/or that some profitable firms incorporate technology via purchases of new machinery or imitation of other firms rather than by patenting of innovations. Another possibility is that some of these successful firms prefer to finance R&D in specialized enterprises rather than to conduct in-house R&D. A number of European firms seem to display relatively

low patenting activity in spite of their good performances. One possible interpretation is that these firms patent most of their inventions in Europe exclusively. As our data reflect patenting in the US, one could draw the erroneous conclusion that European firms are weakly innovative *vis-à-vis* US firms. A second, not exclusive hypothesis, is that European firms chiefly incorporate new technology by methods other than the patenting of inventions. Two facts would support these explanations. First, European firms have shown rapid growth of their fixed assets and capital per worker over the period analysed in this Section. Second, previous research suggests that a number of European food-processing industries are innovation-intensive, a situation positively influencing profit in large firms (Rama, 1994). These findings suggest that learning from spillovers originating in other firms and in research centres could be a significant source of technological progress in this industry in Europe.

On the other hand, the mix of different types of R&D - privately and publicly funded - should also be investigated in this industry. It may well be that European firms rely much more on publicly financed R&D than do firms based in other countries. If this explanation is correct, in European firms, low patenting of inventions would be balanced by adoption of new technology produced by public sources. This situation would implicitly pose the question of which of the two types of R&D funding is the more effective in generating productivity growth (Griliches, 1986) and profitability at the firm level.

The pattern of adoption of technology and its links with economic performance at the firm level are relevant to the selection of effective technological policies. If European processors relied chiefly on the adoption of new equipment, for instance, then incentives to innovation among suppliers and credit at low interest rates for purchases of capital goods would probably be especially desirable actions.

3. Innovative intensity, i.e. the number of patents per unit of sales, is not significantly related to firm size but is related to the home country and to sub-sectors in which the firm is based. Beyond a certain threshold, size is not likely to affect innovativeness. As this part of the study focuses on very large firms, such a threshold is largely surpassed by firms in our sample.

4. At first sight, innovativeness and profitability are unrelated in this industry. This finding, however, conceals within-industry differences. The impact of innovativeness on profit varies depending on the home-country in which the firm is based and on the phase of the business cycle. In a number of firms, especially those based in the US or in Other countries, changes in innovativeness are apparently a consequence of foreseen disadvantages *vis-à-vis* competitors or of different phases of the business cycle.

On the contrary, the association of both variables has a positive but statistically insignificant sign in European firms. If the cause were that they use, as it seems, methods other than the patenting of innovations to incorporate technological progress, then it would be difficult to stimulate increases in innovativeness in these firms. If this interpretation were correct, links between innovation and profitability - links which are a powerful engine of technological progress in other countries - would be tenuous in European food-processing firms. European manufacturers would not be likely to view a clear cause-effect relationship between their own innovative efforts and the profitability of their firms. This perception would render technological policies less effective.

5. Firms in divergent strategic groups within this industry compete with distinctive technological features associated, in turn, with different patterns of use of resources and rates of profit. The highest levels of innovativeness are associated with significant diversification into non-food technological fields. Diversification may be crucial to control the supply of upstream technology, enjoy independence from suppliers and produce (or co-operate in the production of) customized equipment, packaging materials or chemical additives. Conversely, the least innovative firms specialize in food technology (and, to some extent, in biotechnology). The latter seems the commonest pattern in European firms.

6. These technological competencies, as mentioned previously, are associated with different financial strategies and levels of profit. The most innovative firms persistently show the highest levels of profitability and least risk throughout critical phases of the business cycle. More importantly, they are the only ones to make profits above the norm continuously from 1977 to 1989.

On the contrary, the least innovative persistently display the lowest rates of profit. They are able, however, to use their capital efficiently. High rates of rotation of capital are probably connected to their producing a small range of standardized products. Some of these firms are also able to secure a great volume of external funding because they are protected by large industrial-financial groups providing them with low-cost loans, such as some Japanese and probably some French industrial-financial groups.

7. In some cases, strategic groups converge towards similar levels of profitability with different strategies and divergent innovative intensities. Only the most innovative, however, continuously attain extraordinary gains. Different rationalities of profitability may lead to similar profits but some paths seem better than others.

8. Technological experience matters because it helps to transform the firm internally, and hence achieve good performance. Technological experience, however, is insufficient to promote extraordinary earnings if it is not associated with current innovativeness.

9. This research suggests an interest in further investigating forms of incorporation of technology other than by the patenting of inventions. Analysis of spillovers and contract R&D would be useful to understand patterns of technological change in food-processing more adequately. This is especially valid for European firms. We study the “innovation systems” in the next Chapter.

Appendix 6.1: Firms Included in the Sample

Name of Firm	Home Country	*	Name of Firm	Home Country	*
1. AGWAY INC.	US	1	52.JOHN LABATT	Canada	3
2. AJINOMOTO CO. INC.	Japan	2	53.KELLOGG CO.	US	1
3. ALLIED LYONS	UK	3	54.KIRIN BREWERY CO LTD.	Japan	3
4. AMATIL LTD	Australia	2	55.KONINKLIJKE WESSANEN N.V.	Neth'lds	2
5. AMERICAN BRANDS INC.	US	2	56.LAND O'LAKES INC.	US	2
6. ANHEUSER BUSCH CO. INC.	US	3	57.LVMH MOET HENNESSY/LOUIS VUITTON	France	3
7. ARCHER DANIELS MIDLAND CO.	US	2	58.MC CORMICK & CO. LTD.	US	2
8. ARLA	Sweden	2	59.MD FOODS AMBA	Denmark	2
9. ASSOCIATED BRITISH FOODS PLC	UK	2	60.MEIJI SEIKA KAISHA	Japan	2
10.BARLOW RAND LTD	S. Africa	2	61.MELKUNIE HOLLAND	Neth'lds	2
11.BASS PLC	UK	1	62.MOLSON COMPANIES LTD.	Canada	3
12.BEATRICE CO. INC.	USA	2	63.MORINAGA MILK INDUSTRY	Japan	2
13.BESNIER S.A.	France	2	64.NESTLE	Switz'ld	2
14.BOND CORP. HOLDINGS LTD.	Australia	2	65.NICHIREI CORP.	Japan	2
15.BONGRAIN S.A.	France	2	66.NICHIRO GYOGYO KAISHA	Japan	1
16.BOOKER	UK	1	67.NIPPON MEAT PACKERS INC.	Japan	1
17.BORDEN INC.	US	2	68.NIPPON SUISAN KAISHA LTD.	Japan	1
18.BSN GROUP	France	2	69.NISSHIN FLOUR MILLING GO.LTD	Japan	1
19.C.P.C. INTERNATIONAL	US	1	70.NORTHERN FOODS PLC.	UK	2
20.CADBURY SCHWEPPES PLC	UK	2	71.PEPSICO INC.	US	3
21.CAMPBELL SOUP CO.	US	2	72.PERNOD RICARD	France	3
22.CANADA PACKERS INC.	Canada	1	73.PHILIP MORRIS COMPANIES INC.	US	2
23.CARGILL INC.	US	1	74.PILLSBURY CO.	US	2
24.CARLSBERG A/S	Denmark	3	75.PROCTER & GAMBLE CO.	US	2
25.CASTLE & COOKE INC.	US	2	76.PROVENDOR GROUP	Sweden	2
26.CIE FINANCIERE SUCRES ET DENREES	France	1	77.QUAKER OATS COMPANY	US	1
27.COBERCO	Neth'lds	2	78.RALSTON PURINA CO.	US	2
28.COCA COLA CO.	US	3	79.RANK HOVIS MC DOUGALL PLC.	UK	1
29.CON AGRA INC	US	1	80.RJR NABISCO INC.	US	2
30.DALGETY PLC	UK	2	81.S & W BERISFORD LTD.	US	2
31.DEAN FOODS CO.	US	2	82.SAPPORO BREWERIES LTD.	Japan	3
32.DMV CAMPINA	Neth'lds	2	83.SARA LEE CORPORATION	US	2
33.ELDERS IXL LTD.	Australia	1	84.SCOTTISH & NEWCASTLE BREWERIES PLC.	UK	3
34.FERRERO SPA	Italy	2	85.SEAGRAM CO. LTD	Canada	3
35.GENERAL MILLS INC.	US	1	86.SNOW BRAND MILK PRODUCTS CO.	Japan	2
36.GEO HORMEL & CO.	US	1	87.SODIMA	France	2
37.GEORGE WESTON LTD.	Canada	2	88.SOURCE PERRIER	France	3
38.GOLD KIST INC.	US	1	89.SUNTORY LTD	Japan	3
39.GRAND METROPOLITAN PLC	UK	3	90.TAIYO FISHERY CO. LTD.	Japan	1
40.GUINNESS PLC	UK	3	91.TATE & LYLE PLC	UK	1
41.GUYOMARC'H S.A.	France	1	92.TYSON FOODS INC.	US	1
42.H.J. HEINZ COMPANY	US	2	93.UNIGATE PLC	UK	2
43.HANSON PLC	UK	2	94.UNILEVER	Neth./UK	2
44.HEINEKEN N.V.	Neth'lds	3	95.UNION INTERNATIONAL PLC	UK	1
45.HERSHEY FOODS CORP.	US	2	96.UNION LAITIERE NORMANDE	France	2
46.HILLSDOWN HOLDINGS PLC	UK	1	97.UNITED BISCUITS	UK	2
47.HOUSE FOOD INDUSTRIAL CO. LTD.	Japan	2	98.UNITED BRANDS CO.	US	1
48.IMASCO LTD.	Canada	2	99.WHITBREAD & CO. PLC	UK	2

* Industry: definitions are in Table 6.3.2.

7. Inter-firm and national systems of innovation

7.1 User-producer interactions

As explained above in Chapter 5 and in Section 6.2, the food and beverages industry may be particularly focused on market possibilities and the needs of end-users (despite being so often classified as a supplier-dominated industry in the sense of Pavitt's taxonomy). Therefore, we investigate the degree to which market factors are important to this industry as an inspiration to innovations.

Chapter 3 provided the theoretical hypotheses underlying the assumption that user-producer interactions have an impact on the speed and direction of the innovation process, through more intense interaction between users and producers helping producers to identify the needs of users. Proximity in terms such as culture, geography, or common language, facilitates an articulation and understanding of those needs which may in turn become an input to the innovation process. It is important to stress that in practice the producers do not usually interact with the end-users directly. As in all other manufacturing there is a link in-between, most often consisting of a wholesale firm and/or retail firm before the products reach the final users. Attention should also be paid to the duality in the term "user". A firm in this industry may be a user of raw materials from the agricultural and fishing industry but at the same time a producer of the final food products to be consumed by final users.

Some of the CIS data does address user-producer interaction. This is the case for example of the sources of information for innovation activity, where the role of customers, suppliers etc. are assessed. Also the exchange of technology in terms of firms purchasing or selling various forms of technology may be taken as an indirect yardstick of the qualitative aspect of user-producer interaction. We shall return to this measure later.

In Tables 7.1.1 and 7.1.2 results are shown with respect to those of the variables relevant for user-producer interaction in the light of the former question about the importance of different information sources for innovation activity. The tables show mean high scores for the groups, i.e. the share of firms who assess "clients or customers" (for example) as either crucial or very significant as a source of information for innovation in relation to total responses to that question.

Market factors are generally more important than technology factors. Thus, clients or customers come out as the most important source of information for innovation, with suppliers of materials and components and suppliers of equipment as second and third respectively. Except for "conferences, meetings and journals", the technology factors

Table 7.1.1: Selected external sources of innovation assessed as very important or crucial, by country

A: Market factors

Country	Ranking	Clients or Customers	Suppliers of materials or components	Suppliers of equipment	Competitors	Fairs and exhibitions
Belgium	Total	57	36	45	19	36
	Leaders	50	46	55	9*	45
	Laggards	55	23	41	27	14*
Denmark	Total	67	39	35	28	35
	Leaders	60	47	40	20*	13*
	Laggards	67	47	40	40	67
Germany	Total	76	55	56	57	60
	Leaders	75	54	57	54	71
	Laggards	70	56	56	59	52
Ireland	Total	78	49	42	44	46
	Leaders	88	42	33	42	55
	Laggards	79	55	55	46	42
Italy	Total	37#	28	37	20	28
	Leaders	38#	31	36	21	29
	Laggards	35#	26	37	17	30
Netherlands	Total	70	45	44	23	32
	Leaders	65	44	38	21	40
	Laggards	71	44	48	29	19
Norway	Total	54	48	44	12	32
	Leaders	46	58	58	15	35
	Laggards	59	41	29	12*	18*
Spain	Total	58#	7#	61#	78#	53
	Leaders	58#	9*#	73#	79#	52
	Laggards	59#	9*#	50#	72#	47

Notes: Calculated from CIS data

All figures represent percentages of firms assessing as very important or crucial

Only partly comparable

* Less reliable data because of low number of observations

Table 7.1.2: Selected external sources of innovation assessed as very important or crucial, by country

B: Technology factors

Country	Ranking	Conferences, meetings, journals	Technical institutes	Universities and higher education	Government laboratories
Belgium	Total	30	13	12	**
	Leaders	32	**	**	**
	Laggards	27	**	**	**
Denmark	Total	35	15	**	**
	Leaders	33	20*	**	**
	Laggards	53	20*	**	**
Germany	Total	67	8	27	11
	Leaders	71	11	29	14
	Laggards	59	4*	19	4*
Ireland	Total	31	15	13	10
	Leaders	36	18	15	12
	Laggards	24	18	9*	9*
Italy	Total	13	3	2	3
	Leaders	14	3	1*	3
	Laggards	16	2*	3	4
Netherlands	Total	31	**	9	5
	Leaders	33	**	6*	4*
	Laggards	27	**	8	8
Norway	Total	44	25*	5*	12
	Leaders	50	27	**	**
	Laggards	53	35	**	**
Spain	Total	19#	24#	17	13
	Leaders	18#	27#	24	12
	Laggards	9*#	16#	6*	6*

Notes: Calculated from CIS data

All figures represent percentages of firms assessing as very important or crucial

Only partly comparable

* Less reliable data because of low number of observations

** Non-meaningful data because of low number of observations have little importance as a source of information to the innovation process in most countries, for both leaders and laggards. This does not mean that technological institutes, for instance, have no importance for the innovation process. They are not the spark setting off the process, but they may be important in carrying the process through.

There is no clear conclusion that emerges about the sources used by leaders relative to laggards. The only obvious difference identified is that leaders tend to use *more* sources of information than laggards. This result is based on an analysis of all the 13 sources listed in the questionnaire as opposed to the 9 reported in the tables.

Across countries we find differences both in how many firms use each single source of information and in how many firms attach great importance to a broad variety of sources. Thus, we see that German enterprises both assess more sources as important than in other countries and also assess the sources as important by more firms than in other countries. The same goes for Irish and Spanish firms, although not to same extent. More specifically "clients or customers" are particularly important to German and Irish food and beverages firms. The Italian firms within this industry assess this source of information as of very low importance. Suppliers are important to firms in Germany, the Netherlands, Norway and Ireland, but not to Italian firms. Scientific inputs from universities and higher education institutions, government laboratories and technical institutes are relatively important to firms in Germany, Ireland and Spain, but - again - particularly low in Italy. The latter finding corresponds with that of Malerba (1993), who finds that public research played a very weak role in innovation in Italy, and also corresponds with findings in the PACE study.

Large firms tend to use more sources than do other firms. This is however for obvious reasons: a large firm is more likely to have introduced several innovations and it is likely that different products or processes require different information sources. It then follows naturally that the more innovations are introduced, the more sources they tend to use.

The other group of indicators of user-producer interaction mentioned above is acquisition and transfer of different types of technology, regionally distributed. The questionnaire asks whether the firms are engaged in various types of sale and purchase or not, rather than undertaking quantification of these transfers. Results are set out in Tables 7.1.3 and 7.1.4.

In general it seems as if geography matters in terms of where food-processing firms buy their technology. National purchases are by far the most frequent, followed by acquisition from other EU countries. US and Japanese sources are not used by many firms in spite of their advanced technologies. Small and generally technologically less advanced countries, like Denmark and Ireland, are low in national acquisitions and high in EU acquisitions. On the other hand this is not the case for Norway, though it is not an EU member. Nevertheless, the size of the economy seems to be an indication of whether acquisitions take place mainly nationally or from the rest of the EU or other regions. For example, in Germany and Italy, the share of firms who purchase technology nationally is more than double that of firms who acquire from the EU. Conclusions from the literature on globalization resemble those above: the size of the national economy matters for the geography of technology acquisition.

Table 7.1.3: Regional sources for the purchase of technology (percentages)

Country	National source	Other EU country	Non-EU European	USA	Japan	Other source
Belgium	81	72	21	7	4	1
Denmark	67	59	30	11	4	2
Germany	96	41	8	7	2	4
Ireland	65	71	10	14	7	3
Italy	95	33	5	4	2	2
Netherlands	83	44	9	10	1	1
Norway	93	51	na	na	na	na

Table 7.1.4: Regional sources for the sale of technology (percentages)

Country	National source	Other EU country	Non-EU European	USA	Japan	Other source
Belgium	51	82	57	12	30	24
Denmark	54	39	57	11	7	22
Germany	92	24	13	2	0	7
Ireland	35	29	2	21	0	14
Italy	82	32	20	9	3	7
Netherlands	59	52	43	14	4	20
Norway	98	19	na	na	na	na

With regard to the regions to which firms sell technology, the home country is still the most important but - as could be expected - not so frequently as for technology purchases. At first sight it might seem strange that so many more firms buy technology domestically compared to those selling technology. A national acquisition must also result in national sales. But the tables count only the number of firms selling or buying technology, not the number of transactions. Therefore, part of the explanation may be one firm selling to several other firms. Another explanation is that firms may buy technology from the public sector, e.g. technological institutes, or may buy technology (e.g. consultancy services) from outside the manufacturing sector. When it comes to the more distant markets it shows that firms are more prone to sell to non-EU European markets and other areas rather than to North America and Japan.

Large firms are generally more active in both types of technology transfer and the difference relative to smaller firms becomes greater the more distant the country of origin or destination. There are no patterns in differences between leaders and laggards in either purchases or sales.

In essence, national sales and acquisitions are more important than other sources. This may indicate some importance of proximity between users and producers but also that the nation state may have some importance for firms in this sector. This is the issue we now turn to.

7.2 National innovation systems

Amongst both theorists and policy-makers, the concept of the national innovation system is used increasingly frequently. The importance of the elements in a national innovation system (NIS) and the interplay between these elements are now widely recognised. But the concept is still relatively new and calls for further research and practical use.

One definition of a national innovation system claims that it is

> "... constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge and that a national system encompasses elements and relationships, either located within or rooted inside the borders of a nation state." (Lundvall, 1992, p 2)

It is furthermore argued that the nation state has two dimensions - the social-cultural and the étatist-political. It is not necessarily the case that these two dimensions coincide. A nation may thus be defined by its individual cultural, ethnic and linguistic characteristics, but nations, as they are generally perceived, differ in their degree of cultural homogeneity.

The public elements in a system include cultural and social conditions, the financial system, the education system, technological infrastructure and government policies for promoting innovations. Private elements include the way firms organize innovation internally and their interaction with other firms or the technological infrastructure to acquire external information supporting or initiating the innovation process.

The links between elements of the system may be vital for determining how much innovation the firms can undertake. A further reason for this is closely related to why user-producer interaction is better promoted when a certain proximity is present: individuals find it easier to communicate with people with whom they share culture, language and history. These dimensions often coincide with national borders, although the European countries are somewhat diverse in this respect. But what further enhances the importance of nation states is the legislative and political regulatory systems which are primarily national. In addition, the structure of demand is often to some extent a result of the historical evolution of both production and broader societal conditions, as we indicate below.

The notion of a national innovation system is not directly addressed in the CIS. Indirect indicators include the importance of institutions in barriers to innovation and in information sources. The latter gave little importance to the supply-side factors in dictating sources - Germany, Ireland and Spain more than others and Italy much less than others. We also saw (in Tables 7.1.3 and 7.1.4) that proximity matters in respect of acquisitions and sales of technology.

In the PACE study respondents were asked to list the region of origin of the sources of information for innovation. The results from this study further enhance our claim that national innovation systems are of importance, both in general and to the food and beverages industry in particular. Specifically the PACE study shows that there are national differences in the importance of domestic versus foreign sources of information, independently of national differences in industry structure. It is also found that there is a marked effect of cultural distance in the use of information sources for innovation. For example, the general picture is that sources from other European countries are the most important ones, followed by North America and finally Japan. But sources from North America are of greater importance to the UK firms than sources from other countries in Europe, which could be explained by the small cultural distance between the UK and North America as compared to the equivalent distance between the UK and the rest of Europe.

One view of the relative importance of national innovation systems for different industries claims that science-based industries are less dependent on the national innovation system compared to less science-based industries like the food and beverages industry. The PACE study largely confirms this view. Out of 16 investigated industries, firms in the food-processing industry come third in attaching greatest importance to domestic information sources. Public research is assessed as being very important compared to other industries. Across countries the PACE study confirms the findings in the present study: German respondents attach great importance to national sources related to technological infrastructure (technical institutes, universities and higher education institutions and government laboratories) as opposed to Italian firms (especially).

7.2.1 National Patterns in Patenting

Further evidence on regional and national tendencies to innovate may be derived from the patenting patterns. The relevant data are all taken from the numbers of patents granted at the US Patent Office (USPO) between 1969 and 1994. These data are nowadays available on CD-ROM, but working the data from CD-ROM into usable results still involves intensive effort (such as has been required for the company-level data used elsewhere in this Report). However, detailed analysis of these figures in certain respects has recently become more practicable with the development of software by Pari Patel of SPRU.

The results of this section are based on country aggregations, as defined by the USPO and narrowed further by the Patel format. Over the period 1969/94 there were nearly two million patents granted by this Office, almost 60% of which specified the USA itself as the country of invention (see Table 7.2.1). The remaining 40% or so were distributed around other countries of the globe in terms of their country of origin. The basic nature of the data should be stressed from the outset: that what is being referred to is the source country of the patent, not necessarily the country of origin of the company carrying out the patenting. For example, patenting from France may stem from French companies, but may also be from US or Italian companies which happened to carry out patentable activities in France. Conversely, patents from French companies may come from France (the majority seem to), but may also come from foreign activities of French companies, in which case they would be listed under the foreign country.

Table 7.2.1: Numbers of patents, by technological field

Region/ Country	Abbrev.	Patents 1969/94	Share %*	Growth % 1969/73-1990/4	Food Patents 1969/94	Growth % 1969/73-1990/4
All Countries	ALL	1953497	100.00	35.07	23022	8.37
Western Europe	WE	419814	21.49	26.46	5019	65.09
Eastern Europe	EE	12543	0.64	-54.42	111	-20.83

USA	USA	1164474	59.61	1.39	14905	-15.77
Other New World	ONW	44905	2.30	74.90	718	68.81
Latin America	LA	1870	0.10	30.70	57	60.00
Japan	JP	285602	14.62	466.92	1888	179.69
East Asia	EA	12153	0.62	49977.78	122	4050.00
Other Regions	OT	12136	0.62	148.83	202	21.43
Belgium	BE	7299	1.74	22.13	85	-8.00
Switzerland	CH	32547	7.75	0.46	544	148.94
Germany	DE	162938	38.81	40.39	1346	44.33
Denmark	DK	4300	1.02	23.88	129	26.09
Spain	ES	2412	0.57	112.46	85	450.00
Finland	FI	5655	1.35	436.72	60	625.00
France	FR	61656	14.69	44.28	648	65.22
UK	GB	69172	16.48	-19.77	935	29.41
Greece	GR	240	0.06	-3.64	2	-
Ireland	IE	776	0.18	167.00	21	500.00
Italy	IT	23398	5.57	80.85	412	213.16
Netherlands	NL	19138	4.56	41.11	426	79.37
Norway	NO	2475	0.59	48.70	32	-30.00
Austria	OE	7555	1.80	51.27	68	40.00
Portugal	PT	116	0.03	-4.00	4	200.00
Sweden	SE	20137	4.80	-6.30	224	2.50

Notes: * Share of All Countries for Regions; share of Western Europe totals for Countries.
Food patents comprise Food (including sugars), Food and beverage apparatus, and Tobacco.
WE includes only the larger countries of Western Europe (as detailed in the lower panel); EE excludes East Germany; ONW is Canada, Australia and New Zealand; LA is Brazil and Mexico only; EA is South Korea and Taiwan only.

A further problem is that, for USPO data, the USA itself is the “home country”. According to the figures in Table 7.2.1, total patents from US sources have scarcely changed between the initial quinquennium, 1969/73, and the final one, 1990/4; while the overall totals have risen by more than one-third. Thus the US share in patenting in the USA has dropped. However this does not necessarily signify declining competitiveness (in terms of patents granted) for the USA. The expansion of other countries in their patents and patent shares in US patenting has come about partly because of growing internationalization, implying that firms of foreign countries have become more concerned with patenting in the USA, and no doubt in other countries apart from their own as well. How much of the US relative decline is simply this “home country” effect cannot be estimated from these data alone. For more recent times, comparisons can be drawn with patenting at the European Patent Office (EPO), but this too is not undertaken here. For the EPO, of course, the converse situation would apply regarding European companies.

With such limitations in mind, we can nevertheless draw certain inferences about the country orientation of patenting. Table 7.2.1, and the remaining tables of this section, list global regions, and also list separately the major countries of Western Europe. In most of the subsequent tables, abbreviations will be used for the regions or countries; these are given in the second column of this Table. The first two data columns give totals of patents from each of these sources for the whole period and the associated share (share in Western European total for the specific countries). The next column gives the simple percentage growth for all patents of the country/region between the first quinquennium and the final one. The last two columns treat "food" patents alone, here defined as the sum of food proper, food and beverage apparatus, and tobacco.

East Asia (South Korea and Taiwan) shows enormous growth in percentage terms, partly because of the very small initial base. Japan also shows high rates of growth, and over the period as a whole received about two-thirds of the numbers of patents granted to Western Europe in total. Eastern Europe shows an absolute as well as relative decline, of considerable proportions - this decline actually began in the 1980s before the end of communism, though it has accelerated to date in the post-communist period. Other regions show a degree of "catching up", at least as measured through the growth percentage. A similar "catching up" process is partly evident in Europe, as shown by the figures for Finland, Spain, Ireland and Italy, both for all patents and for food patents; although some countries like Portugal and Greece still appear to be excluded in terms of patenting.

Table 7.2.2 breaks down the column of All Patents in Table 7.2.1 (i.e. first data column), as percentages by technological field. The columns of fields defined towards the left-hand side of the Table are regarded as food or food-related, though to lesser degrees as one moves rightwards. The columns towards the right are regarded as having some possible links with food processing, though they might be of quite small magnitude relative to all their foci. At the regional level, the shares of food and food equipment patents appear to be strongly correlated with land availability - the land-abundant countries of Latin America and the New World contrasting with the land-scarce countries of East Asia, including Japan. Within Western Europe, there seems to be a different factor operating, in which countries with considerable histories of machine-based food production (Denmark, Ireland, Netherlands, etc.) feature among those with relatively high shares. These two factors might well be linked at the regional level, as for instance via the argument of Hayami and Ruttan (1971), that land-abundant countries adopt machine-intensive methods of land cultivation, which indeed seems borne out by the column relating to agricultural machinery. However for tobacco there seems to be surprisingly little link between growing the raw produce and patenting ways of processing it (see the third column of the Table). Climate appears to have some impact on the patenting of refrigeration equipment and procedures.

Table 7.2.2: Percentage of patents by technological field, 1969/94

Field:	Food	Food Eqpt	Tob-acco	Agric Machy	Refrig	Bio-tech	Chems	Drugs	Mater	Elect	Instrts	Other
ALL	74	26	17	65	35	105	1871	272	408	1557	1374	4195
WE	65	29	26	55	18	95	2216	419	402	1169	1177	4330
EE	65	27	5	50	17	147	2364	521	314	622	1570	4299
USA	84	27	17	78	39	104	1854	232	378	1485	1323	4377
ONW	97	44	18	187	40	107	1452	217	371	1026	1133	5307
LA	171	123	11	118	37	64	1759	348	652	642	850	5225
JP	49	12	5	11	39	119	1549	222	559	2541	1883	3010
EA	17	61	22	9	72	25	653	55	184	2186	1749	4967
OT	82	59	26	68	43	174	1626	370	279	913	1466	4895
BE	79	32	5	136	12	141	2683	510	836	1600	743	3224
CH	112	27	29	96	14	94	2870	532	269	749	1320	3888
DE	38	20	24	36	14	80	2495	333	412	995	1194	4358
DK	200	84	16	47	126	333	1719	670	426	735	1063	4584
ES	133	95	25	37	21	95	1542	655	294	522	854	5626
FI	90	16	0	48	2	126	1533	129	302	2874	852	4028
FR	60	30	15	55	14	94	1899	499	372	1569	1143	4250
GB	73	17	46	38	14	95	1952	554	452	1339	1253	4167
GR	0	0	83	42	42	83	2500	292	708	1208	792	4250
IE	142	64	64	90	26	116	1637	438	219	1456	1327	4420
IT	52	74	50	41	32	114	2237	605	387	1138	815	4456
NL	155	52	15	167	21	101	2175	197	406	2335	1060	3314
NO	89	36	4	109	28	137	1240	214	331	792	764	6255
OE	48	40	3	95	19	98	1436	214	426	690	1067	5865
PT	86	86	0	172	0	345	2845	431	172	517	862	4483
SE	74	26	11	55	51	118	1227	213	315	923	1186	5802

Note: All figures are percentages of Regional or National totals.
Key: Fields: Food Eqpt = Food and Beverage Apparatus;
Agric Machy = Agricultural Machinery;
Refrig = Refrigeration;
Biotech = Bioengineering;
Chems = Chemicals;
Drugs = Pharmaceuticals;
Mater = Materials (principally glass and plastics, also superconductors);
Elect = Electronics;
Instrts = Instruments;
Other (includes other machinery, metals, paper and print, textiles, vehicles, construction).
Regions / Countries: see Table 7.2.1.

The other side of the Hayami-Ruttan argument is that land-deficient countries should focus more on biological and chemical means of solving agricultural problems. This gets only very limited support from the Table, probably because food-related aspects are only a minority of the activities encompassed by these fields. The main factor that seems to account for strength in areas like biotechnology and pharmaceuticals, at least in looking at patenting by European countries, would seem to be the science base. However it was implied in Chapter 5 of this Report that Japanese food companies have shown rapid increases in the proportions of their patenting from biotechnology and drugs, and to that extent the Hayami-Ruttan argument could be re-established. Where Japan and East Asia score highly, according to the present table, is in the somewhat predictable areas of electronics and instrumentation. Western Europe is rather low in these fields.

The next table, Table 7.2.3, shows the change in terms of percentage points between the first sub-period, here 1969/74, and the final one, which remains as 1990/4. The absolute values of course influence the extent of change, so to compare columns one might also relate these percentage point differences to differing means, as in the preceding table. Most regions see a decline in the food and food-related areas (first three data columns), but Western Europe shows some increase. All areas except Japan show a rise in the share of biotechnology (in Japan and East Asia it is being overshadowed by the very rapid growth of total patenting), and a rise in pharmaceuticals that is generally about twice as large, while other chemicals are relatively shrinking. The regional specificity of the growth of electronics is evident, and corresponds generally with the pattern of growth of instruments. Within Western Europe, the growth of biotechnology appears to be fairly well distributed across countries, though some of the disadvantaged countries like Greece or Portugal seem to be slipping back in some of the high-tech areas. Food patents have grown rapidly in Switzerland, the Netherlands and Sweden, as shown in Figure 7.1.

Table 7.2.4 gives the shares in patenting in each of the fields displayed.. The USA shares are influenced by the "home country" factor described above. Its shares are highest for the categories of agricultural machinery, refrigeration and food, which supports the view of the US as still a resource-based economy (Wright, 1990). The percentages are of course affected by the levels of aggregation, which are here much more detailed in such fields as compared with chemicals, electronics, etc. For Western Europe, the highest shares are for drugs and tobacco; while the lowest shares apart from refrigeration go to electronics, agricultural machinery, instruments, food and biotechnology. Considerable variability is evident across particular European countries. This is also the case for food patents as displayed in Figure 7.2. The same figure illuminates an argument that we put forward earlier: the CIS data are not covering all the major players in food and beverages. The UK, France, and Switzerland especially, also Sweden, are among the countries most active in food patenting, but they are not adequately represented in the CIS data.

Figure 7.1: Change in Food patent <u>*shares*</u> *for Western European major players, 1969/74 to1990/94,%*

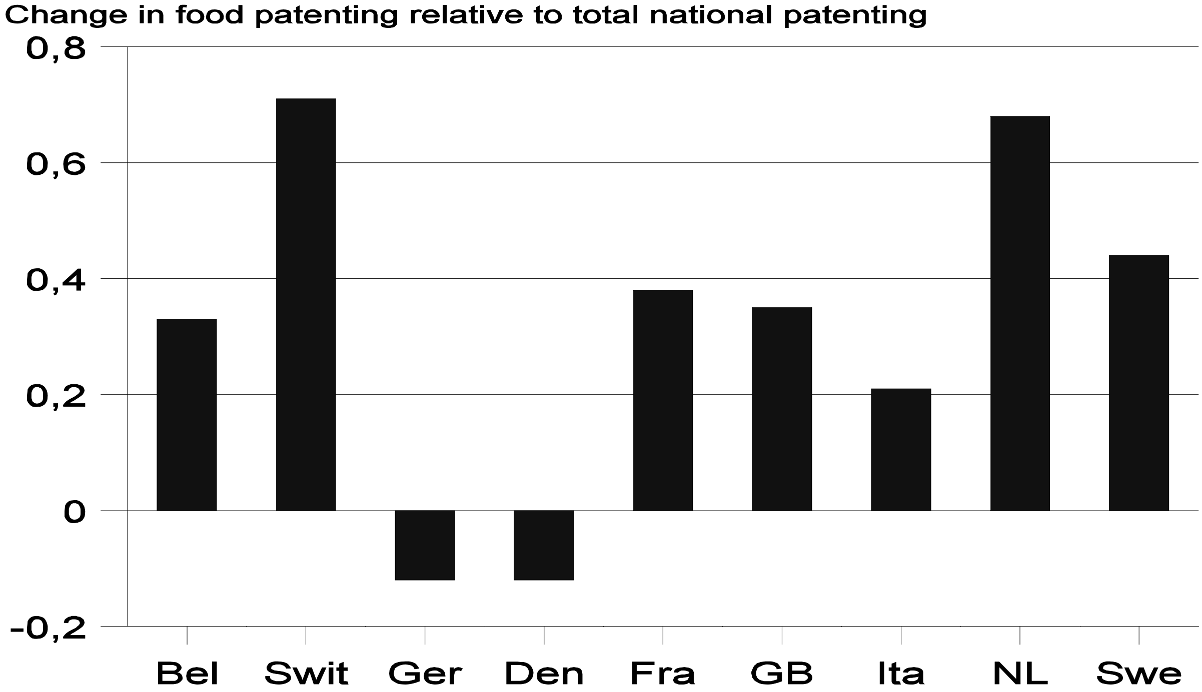


Figure 7.2: Share of Food patents for Western European major players, 1969/74 to1990/94,%

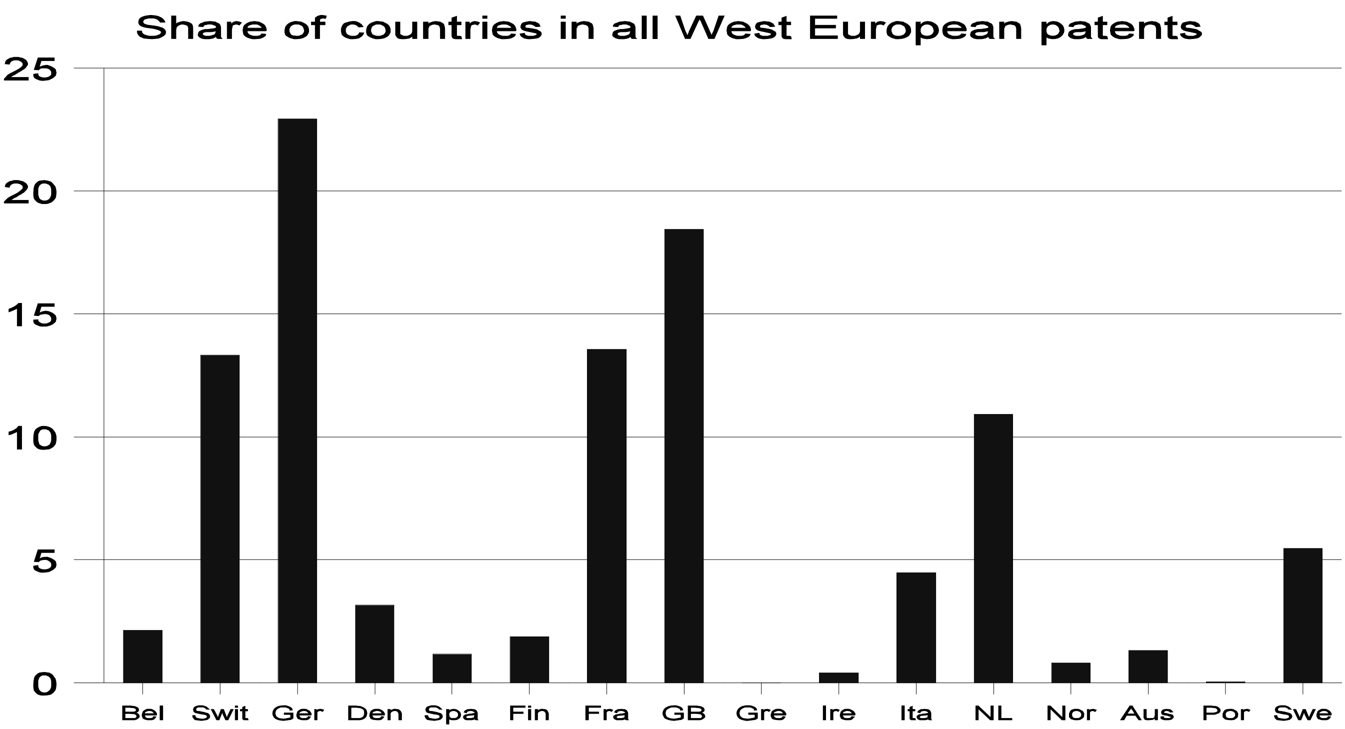


Table 7.2.3: Change in Patent Shares, by Technological Field, 1969/74 to 1990/4, %

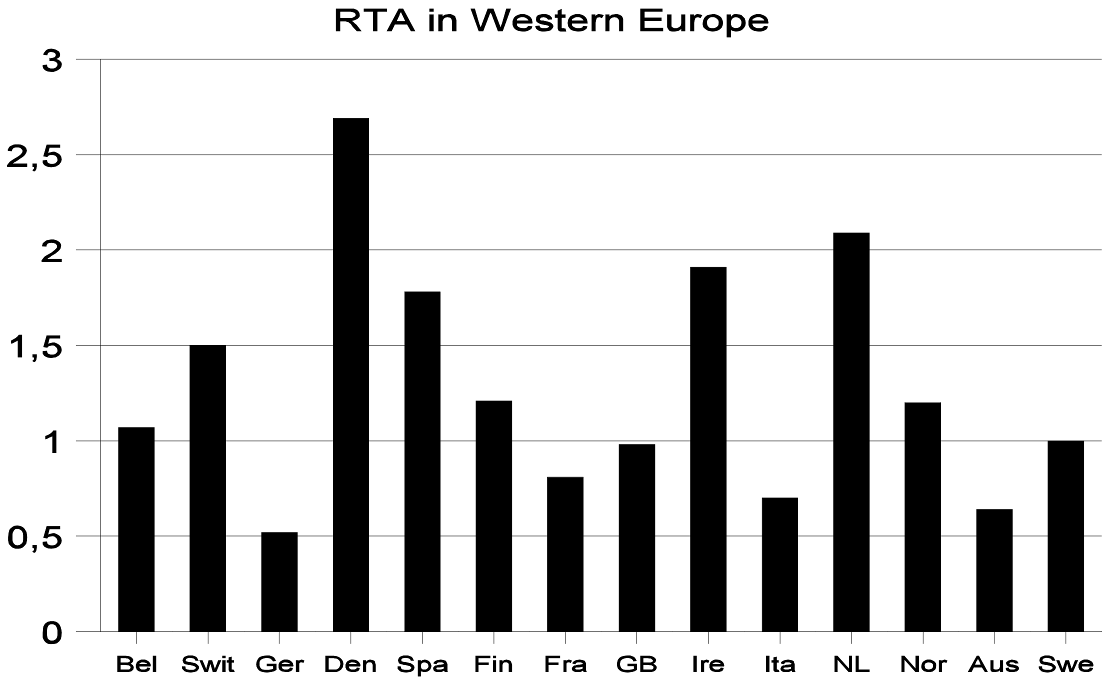
Field:	Food	Food Eqpt	Tob-acco	Agric Machy	Refrig	Bio-tech	Chems	Drugs	Mater	Elect	Instrts	Other
ALL	-0.11	-0.10	-0.04	-0.44	0.06	1.13	-3.99	2.60	0.69	5.83	3.24	-8.89
WE	0.25	0.01	0.02	-0.13	-0.02	1.09	-2.68	4.42	0.51	1.05	1.34	-5.86
EE	0.55	-0.13	0.24	0.17	0.23	1.70	2.15	12.98	-0.51	-2.69	1.81	-16.49
USA	-0.08	-0.11	-0.03	-0.47	0.06	1.45	-3.01	2.56	0.32	3.51	2.90	-7.10
ONW	0.03	-0.03	0.00	-0.42	0.24	1.53	-4.24	2.35	0.73	0.39	3.49	-4.06
LA	-0.16	1.08	0.00	-0.30	1.12	0.88	-9.96	-0.01	0.78	-1.39	-1.89	9.85
JP	-0.43	-0.05	-0.05	0.03	0.15	-0.63	-7.97	1.20	1.15	11.75	1.72	-6.87
EA	0.16	0.55	-7.79	0.09	0.74	0.28	-5.33	0.57	-2.07	5.78	10.13	-3.10
OT	-0.67	-0.18	-0.51	-0.64	0.11	1.52	-3.98	3.68	-1.09	6.44	5.30	-9.97
BE	0.33	-0.52	-0.06	-0.51	-0.18	1.99	4.02	6.65	0.56	-10.75	1.59	-3.14
CH	0.71	0.24	0.12	-0.64	0.00	1.06	-8.13	2.59	0.78	-0.34	1.01	2.62
DE	-0.12	-0.01	0.03	-0.11	0.05	0.87	-2.43	3.16	0.98	-0.08	0.46	-2.96
DK	-0.12	-0.01	-0.10	0.83	-0.32	4.86	-3.41	14.50	0.37	-3.20	3.75	-17.13
ES	1.07	1.52	-0.10	-0.47	0.04	1.44	-1.16	5.28	-2.04	-0.89	5.57	-10.27
FI	0.46	-0.38	--	0.05	0.00	1.22	2.70	1.65	1.88	7.41	1.76	-16.75
FR	0.38	-0.09	-0.16	0.07	0.03	1.05	-3.07	4.86	0.71	4.16	0.91	-8.86
GB	0.35	-0.10	0.19	0.00	0.04	1.36	-2.68	8.17	-0.40	2.72	4.19	-13.83
GR	--	--	1.89	0.00	-1.39	3.77	0.31	0.50	-8.73	-2.96	8.15	-1.55
IE	0.27	0.75	0.37	-0.48	0.37	1.39	-6.82	7.87	-2.40	18.84	1.89	-22.06
IT	0.21	0.36	0.29	0.09	-0.12	0.87	-6.41	6.28	0.09	-1.33	2.36	-2.67
NL	0.68	-0.14	-0.04	-1.39	-0.16	1.20	-1.91	1.60	0.06	1.97	4.97	-6.84
NO	-0.63	-0.63	0.17	-0.98	-0.45	1.60	-4.12	4.53	-2.91	0.47	1.13	1.82
OE	-0.02	0.00	-0.07	0.00	-0.23	1.48	2.59	3.18	1.01	-1.07	-0.22	-6.64
PT	4.17	-3.23	--	8.33	--	-6.45	11.69	12.50	4.17	-5.51	-22.58	-3.09
SE	0.44	-0.12	-0.17	0.31	-0.42	1.07	-2.03	2.32	0.85	0.92	4.20	-7.37

Note: All figures represent changes in the field‘s share in total regional or national patenting between the beginning and end periods defined.
-- indicates no patents in this field.
For abbreviations and definitions, see Tables 7.2.1 and 7.2.2.

The patterns are more easily identified from Table 7.2.5, which computes the "Revealed Technological Advantage" (RTA) for each case. The RTA is now a well-known measure of comparative technological advantage, being the relative share of a country in a particular technology - relative, that is, to the country's own totals and to world averages. USA figures tend to lie close to unity, the median value, because of the large-country effect. In food, Western and Eastern Europe, Japan and East Asia all lie below unity, indicating a comparative disadvantage; though for food equipment, only Japan lies in this category. Other regional patterns are as already described, with Western Europe being below average in biotechnology, electronics and instruments, among other things. For the individual West European countries, we see in Figure 7.3 that Germany is well below average in food and food equipment, while Austria, Italy and France are also low in terms of food patents. Denmark and the Netherlands top the RTAs for food, with Ireland, Spain and Switzerland also with high levels.

Figure 7.3: RTA for Food products for Western European major players, 1969/74

to1990/94,% RTA.



The list of countries indicates a variety of possible reasons, but what does seem apparent is the niche that the industry offers for technological development in medium-sized countries. Agricultural machinery is generally correlated with food, though Denmark and Spain are exceptions to this (Denmark pulls up in refrigeration). In biotechnology, again Germany fares badly and Denmark does very well, while in drugs most of the larger European countries (apart from Sweden and the Netherlands) perform well. Conversely in electronics, most of the large countries are below average, while in instruments all the West European countries are below average. In the light of what we have had to say in Chapter 5 about the importance of instrumentation, this appears rather worrying.

Table 7.2.4: Percentage Share of Countries in All or West European Patents, by Technological Field, 1969/94

Field:	Food	Food Eqpt	Tob-acco	Agric Machy	Refrig	Bio-tech	Chems	Drugs	Mater	Elect	Instrts	Other
WE	18.74	23.45	32.43	18.06	11.24	19.53	25.35	32.90	21.12	16.42	18.35	22.16
EE	0.56	0.66	0.18	0.50	0.31	0.90	0.81	1.23	0.49	0.26	0.73	0.66

USA	67.00	62.02	58.93	71.43	67.25	59.37	59.10	50.96	55.36	56.73	57.45	62.20
ONW	3.01	3.86	2.46	6.63	2.64	2.34	1.78	1.84	2.09	1.51	1.90	2.91
LA	0.22	0.45	0.06	0.17	0.10	0.06	0.09	0.12	0.15	0.04	0.06	0.12
JP	9.64	6.72	4.21	2.48	16.40	16.62	12.11	11.97	20.07	23.81	20.05	10.49
EA	0.14	1.44	0.80	0.09	1.28	0.15	0.22	0.13	0.28	0.87	0.79	0.74
OT	0.68	1.40	0.92	0.65	0.77	1.03	0.54	0.85	0.42	0.36	0.66	0.72
BE	2.13	1.91	0.37	4.33	1.18	2.57	2.11	2.13	3.63	2.33	1.10	1.30
CH	13.33	7.23	8.60	13.72	6.04	7.62	10.09	9.93	5.22	4.87	8.72	6.97
DE	22.92	27.35	35.96	25.47	29.40	32.51	43.90	31.08	39.97	32.39	39.52	39.11
DK	3.16	2.99	0.64	0.87	7.09	3.57	0.80	1.65	1.09	0.63	0.93	1.09
ES	1.18	3.91	0.55	0.39	0.66	0.57	0.40	0.91	0.42	0.25	0.42	0.75
FI	1.87	0.75	0.00	1.18	0.13	1.77	0.94	0.42	1.02	3.25	0.98	1.25
FR	13.55	15.38	8.60	14.85	11.42	14.47	12.64	17.65	13.65	19.32	14.31	14.43
GB	18.44	9.73	28.91	11.40	12.34	16.42	14.58	22.00	18.61	18.51	17.61	15.87
GR	0.00	0.00	0.18	0.04	0.13	0.05	0.06	0.04	0.10	0.06	0.04	0.06
IE	0.40	0.42	0.46	0.31	0.26	0.22	0.14	0.20	0.10	0.23	0.21	0.19
IT	4.48	14.38	10.70	4.24	9.84	6.67	5.65	8.12	5.38	5.32	3.87	5.74
NL	10.91	8.31	2.65	13.98	5.38	4.82	4.49	2.16	4.62	8.93	4.12	3.49
NO	0.81	0.75	0.09	1.18	0.92	0.85	0.33	0.30	0.49	0.39	0.38	0.85
OE	1.32	2.49	0.18	3.15	1.84	1.85	1.17	0.93	1.91	1.04	1.64	2.44
PT	0.04	0.08	0.00	0.09	0.00	0.10	0.04	0.03	0.01	0.01	0.02	0.03
SE	5.47	4.32	2.10	4.81	13.39	5.92	2.67	2.45	3.77	3.71	4.85	6.43

Note: Regional figures (top panel) are percentages of All patenting; Country figures (bottom panel) are shares in West Europe totals.

For abbreviations and definitions, see Tables 7.2.1 and 7.2.2.

The remaining tables in this section undertake correlation and cluster analyses of these panels of data in Table 7.2.5 just described. Because of the problems of handling the RTA index, i.e. its tendency to produce a non-normal distribution, especially for small countries or fields, the correlations and clusters have used transformed data. The transformation employed is a simple one, with the RTAs transformed to the value of the natural logarithm of (RTA + 1). Apart from correcting for some lognormality in the raw data, this transformation also has the advantage of producing very similar results to transformations aimed specifically at inducing normality, such as the arctan distribution. The median value is now ln(2), i.e. 0.693, rather than 1, but that can be corrected by another very simple transformation if required. Several of the correlations were also run on untransformed data, with little significant effect on the results.

Table 7.2.5: Revealed Technological Advantage (RTA) by Region or Country, 1969/94

Field:	Food	Food Eqpt	Tob-acco	Agric Machy	Refrig	Bio-tech	Chems	Drugs	Mater	Elect	Instrts	Other
WE	0.87	1.10	1.53	0.84	0.53	0.91	1.18	1.54	0.99	0.75	0.86	1.03
EE	0.88	1.03	0.28	0.77	0.48	1.40	1.26	1.92	0.77	0.40	1.14	1.02
USA	1.12	1.04	0.99	1.20	1.13	1.00	0.99	0.85	0.93	0.95	0.96	1.04
ONW	1.31	1.68	1.07	2.88	1.15	1.02	0.78	0.80	0.91	0.66	0.82	1.27
LA	2.30	4.68	0.62	1.81	1.08	0.61	0.94	1.28	1.60	0.41	0.62	1.25
JP	0.66	0.46	0.29	0.17	1.12	1.14	0.83	0.82	1.37	1.63	1.37	0.72
EA	0.23	2.32	1.28	0.14	2.06	0.24	0.35	0.20	0.45	1.40	1.27	1.18
OT	1.10	2.26	1.48	1.05	1.23	1.66	0.87	1.36	0.68	0.59	1.07	1.17
BE	1.07	1.20	0.32	2.09	0.35	1.35	1.43	1.88	2.05	1.03	0.54	0.77
CH	1.50	1.02	1.67	1.49	0.41	0.89	1.53	1.96	0.66	0.48	0.96	0.93
DE	0.52	0.77	1.39	0.55	0.40	0.76	1.33	1.22	1.01	0.64	0.87	1.04
DK	2.69	3.18	0.94	0.72	3.61	3.17	0.92	2.47	1.04	0.47	0.77	1.09
ES	1.78	7.41	1.44	0.57	0.60	0.91	0.82	2.41	0.72	0.34	0.62	1.34
FI	1.21	0.61	--	0.74	0.05	1.20	0.82	0.48	0.74	1.85	0.62	0.96
FR	0.81	1.14	0.88	0.85	0.41	0.90	1.01	1.84	0.91	1.01	0.83	1.01
GB	0.98	0.64	2.64	0.58	0.39	0.91	1.04	2.04	1.11	0.86	0.91	0.99
GR	--	--	4.82	0.64	1.20	0.79	1.34	1.07	1.74	0.78	0.58	1.01
IE	1.91	2.45	3.72	1.39	0.74	1.11	0.87	1.61	0.54	0.94	0.97	1.05
IT	0.70	2.81	2.89	0.64	0.92	1.09	1.20	2.23	0.95	0.73	0.59	1.06
NL	2.09	1.99	0.88	2.57	0.62	0.96	1.16	0.73	1.00	1.50	0.77	0.79
NO	1.20	1.38	0.23	1.68	0.81	1.31	0.66	0.79	0.81	0.51	0.56	1.49
OE	0.64	1.51	0.15	1.47	0.53	0.93	0.77	0.79	1.05	0.44	0.78	1.40
PT	1.16	3.28	--	2.65	--	3.29	1.52	1.59	0.42	0.33	0.63	1.07
SE	1.00	0.98	0.66	0.84	1.46	1.12	0.66	0.78	0.77	0.59	0.86	1.38

Note: All figures are RTAs relative to world totals and field shares.
The RTA is calculated as the share of the field in the country or regional total divided by the field's share in the overall total (see Table 7.2.2).
-- indicates no patents in this field.
For abbreviations and definitions see Tables 7.2.1 and 7.2.2.

The correlations displayed in these tables are shown as their probability levels, given the number of degrees of freedom, in order to make comparisons most evident. Negative simple correlations are shown by minus signs in front of the probability levels. Values significant at the .05 (5%) level are shown in bold type. Cases where the untransformed data gave significant results while the transformed data (as shown) did not are marked with asterisks. Because of the nature of the RTA data, where the values are not independent of one another, negative as well as positive correlations are very likely. Strictly speaking, this lack of independence invalidates the regression analysis deployed, but the infringements involved are unlikely to be serious enough to undermine the broad conclusions.

The cluster analyses are carried out as in Section 6.3 of this Report, using the K-means procedure. The number of clusters (K) varies between 2 and 5, and is the result of experimentation with the data. The two panels display which field or country/region is assigned to which cluster, and secondly display the F values for discriminating between the relevant country/region or field in terms of this assignment to a cluster. Thus in Table 7.2.6, the bottom panel shows that the USA, Other New World, Latin America and Japan were significant at the .05 level or better in assigning the chosen technological fields of the first panel to the first case, of two clusters. In this particular example, the second of the two clusters was composed of food, food equipment and agricultural machinery, hence the high values recorded for the USA etc. RTAs in these areas plus low values for Japan have dictated the outcome. Similar arguments prevail in all other cases.

Tables 7.2.6 and 7.2.7 use regional data, i.e. the upper panel of Table 7.2.5 (transformed). The correlations in Table 7.2.6 show strong positive relationships between the "land-abundant" countries of the USA, Other New World, and Latin America, and one strong negative correlation with the "land-scarce" country of Japan. This supports the findings already described. As just noted in the example, the cluster analysis at the level of 2 clusters does likewise. The 4-cluster level shows another cluster of fields relating to electronics, instruments, refrigeration, along with tobacco, in which West Europe generally does rather badly (though - probably because of the tobacco - its impact is not significant).

Table 7.2.6: Correspondences among regional data, by region

1) Correlation coefficient probabilities (zero-order)

Region:	WE	EE	USA	ONW	LA	JP	EA
EE	.297						
USA	-0.059	-0.264					
ONW	-0.609	-0.739	**0.002**				
LA	0.860	0.562	0.256	**0.044**			
JP	-0.177	0.811	-0.102	**-0.004**	-0.118		
EA	-0.451	-0.108	0.879	-0.753	0.828	0.69	
OT	0.344	0.398	0.698	0.282	0.131*	-0.105	0.418

Notes: All figures represent probabilities of not rejecting the null hypothesis of no correlation (n = 12). Minus signs in front indicate negative simple correlations.
All data based on transformed RTAs (= ln(RTA + 1)).
Bold data show significant positive or negative correlations at 0.05 level.
* indicates correlation significant at 0.05 level using untransformed RTAs.

2) Cluster Analysis

Cluster Membership:	2 Clusters	4 Clusters
Food	2	4
Food Equipment	2	2
Tobacco	1	1
Agricultural Machinery	2	4
Refrigeration	1	1
Biotechnology	1	3
Chemicals	1	3
Drugs	1	3
Materials	1	3
Electronics	1	1
Instruments	1	1
Other Fields	1	3

Discriminating probability (F values)	2 Clusters	4 Clusters
West Europe	.702	.611
East Europe	.981	.104
USA	.023	.077
Other New World	.002	.038
Latin America	.002	.001
Japan	.034	.256
East Asia	.727	.002
Other Regions	.302	.192

Table 7.2.7 examines these data by field rather than by region. Relatively high patenting in food is positively correlated with agricultural machinery and negatively with instruments and electronics Food and beverage apparatus is significantly correlated only with Other fields, no doubt because the latter are dominated by mechanical engineering. Agricultural machinery is also correlated with Other fields at the 10% level, and negatively with instruments at almost the 1% level. Tobacco has no significant correlations, while refrigeration has strong negative correlations with chemicals and drugs, despite being in part a chemicals technology. As expected, chemicals and drugs are themselves very strongly intercorrelated. The clusters isolate Japan and East Asia at the 2-cluster level, with electronics and instruments evidently important in this outcome (also food at the .05 level).

Table 7.2.7: Correspondences among regional data, by technological field

1) Correlation coefficient probabilities (zero-order)

Field:	Food Eqpt	Food acco	Tob- Machy	Agric	Refrig tech	Bio-	Chems	Drugs	Mater	Elect	Instrts
Food Eq.	.207										
Tobacco	-.778	.487									
Agric M.	**.015**	.318	.675								
Refrig	-.451	.374	.468	-.614							
Biotech	.546	-.296	-.631	.594	-.145						
Chems	.211	-.483	-.476	.442	**-.000**	.071					
Drugs	.192	-.864	-.569	.453	**-.003**	.056	**.001**				
Mater.	.069	.900	-.215	.503	-.434	.814	.290	.428			
Elect.	**-.047**	-.238	1.000	-.056	.160	-.370	-.115	**-.032**	-.770		
Instrts	**-.007**	-.108	-.573	**-.011**	.538	.820	-.399	-.396	-.242	.063	
Other	.352	**.015**	.167	.092	.539	-.471	-.578	-.857	-.460	-.137	-.098

Notes: as for Table 7.2.6, except n = 8; correlations of untransformed data not calculated.

2) Cluster Analysis

Cluster Membership:	2 Clusters	4 Clusters
West Europe	2	4
East Europe	2	4
USA	2	4
Other New World	2	4
Latin America	2	2
Japan	1	1
East Asia	1	3
Other Regions	2	1

Discriminating probability (F values)	2 Clusters	4 Clusters
Food	.043	.006
Food Equipment	.557	.038
Tobacco	.624	.480
Agricultural Machinery	.020	.190
Refrigeration	.125	.340
Biotechnology	.236	.072
Chemicals	.052	.097
Drugs	.046	.177
Materials	.747	.011
Electronics	.004	.045
Instruments	.039	.051
Other Fields	.220	.056

Tables 7.2.8 and 7.2.9, give the results for West European countries, i.e. the lower panel of Table 7.2.5. The correlations of country data in Table 7.2.8 do not always make a great deal of sense, for example in showing Greece as being positively correlated only with Germany and the UK, or Portugal with Belgium, Norway and Austria. The cluster analyses give some information on why this is so, especially when it is recalled from the discussion of Table 7.2.5 that there was a large amount of variability evident in the raw data across European countries. Cluster

membership of the various fields is very unstable as one goes from the 2-cluster analysis to the 5-cluster one. However at both of these levels, the extremes of Table 7.2.8, there is a group of food, agricultural machinery, biotechnology, drugs and other fields (also food equipment in the 2-cluster assignment). From the summary of the ANOVA table, we can see that it is basically the smaller countries that are dictating the results (especially Spain, Greece, Ireland, Norway and Portugal) - hence the instability.

Analyses of the same panel of data at the level of technological fields, in Table 7.2.9, are in a way simpler, because there is only one significant positive correlation, namely that between food and food equipment. This is another reflection of the variability across countries. Study of the cluster memberships in the second panel reveals, as expected from what has just been said, many strange bedfellows. At the 2-cluster level, this is because tobacco is the only significant determinant. When we move to the 4 or 5 cluster level, we can see that other food-related areas plus biotechnology come in as significant determinants, and with odd exceptions the patterns of cluster membership begin to make rather greater sense. The overriding impression however remains one of cross-country diversity.

Table 7.2.8: Correspondences among West European data, by country

1) Correlation coefficient probabilities (zero-order)

Ctry:	BE	CH	DE	DK	ES	FI	FR	GB	GR	IE	IT
CH	.399										
DE	.835	.088									
DK	-.863	-.913	-.282								
ES	.808	.260	.617	.076							
FI	.140	-.579	-.497	-.468	-.602						
FR	.078	.063	**.046**	-.835	.130	.490					
GB	-.851	**.035**	**.002**	-.532	-.650	-.372	.066				
GR	-.375	.753	**.037**	-.248	-.265	-.066	-.866	**.025**			
IE	-.431	**.037**	.453	.625	**.031**	-.253	.440	**.024**	.690		
IT	-.761	.178	.060	.344	**.006**	-.091	.111	**.047**	.294	**.009**	
NL	.150	.499	-.179	-.776	.461	.166	-.961	-.275	-.060	.387	-.653
NO	.131	.977	-.150	.245	.368	.277	.967	-.058	-.023	-.713	-.500
OE	.052	-.977	-.653	.743	.302	.348	.501	-.105	-.062	-.442	-.701
PT	**.031**	.251	-.869	.348	.134	.205	.173	-.450	-.044	.739	.759
SE	-.322	-.246	-.127	**.034**	.717	-.615	-.161	-.098	-.357	-.540	-.614

(cont'd)	NL	NO	OE	PT
NO	.112			
OE	.247	**.000**		
PT	.096	**.006**	**.007**	
SE	-.451	.052	-.266	.771

Notes: as for Table 7.2.6. For country abbreviations see Table 7.2.1.

2) Cluster Analysis

Cluster Membership:	2 Clusters	3 Clusters	4 Clusters	5 Clusters
Food	2	1	4	1
Food Equipment	2	2	2	2
Tobacco	1	3	3	3
Agricultural machinery	2	1	4	1
Refrigeration	1	1	1	5
Biotechnology	2	1	4	1
Chemicals	1	1	4	4
Drugs	2	2	2	1
Materials	1	1	4	4
Electronics	1	1	4	4
Instruments	1	1	1	4
Other Fields	2	1	4	1

Table continued overleaf.

Table 7.2.8 (cont'd); *2) Cluster Analysis* (cont'd)

Discriminating probability	2 Clusters		3 Clusters		4 Clusters		5 Clusters	
Belgium	.183		.208		.022		.218	
Switzerland		.205		.274		.304		.229
Germany	.570		.232		.320		.275	
Denmark	.138		.315		.450		.082	
Spain		.074		.004		.013		.006
Finland	.387		.117		.017		.065	
France	.198		.046		.021		.284	
UK		.785		.023		.043		.058
Greece	.063		.016		.050		.022	
Ireland	.341		.003		.009		.002	
Italy		.664		.000		.000		.056
Netherlands		.183		.851		.447		.558
Norway	.001		.148		.169		.011	
Austria	.034		.076		.120		.064	
Portugal	.003		.157		.102		.021	
Sweden	.216		.596		.553		.065	

Note: discriminating probability based on F values from ANOVA table.

Table 7.2.9: Correspondences among West European data, by technological field

1) Correlation coefficient probabilities (zero-order)

Field:	Food Eqpt	Food acco	Tob-Machy	Agric	Refrig	Bio-tech	Chems	Drugs	Mater	Elect	Instrts
Food Eq.	**.007**										
Tobacco	-.386	-.635									
Agric M.	.254	.557	-.064								
Refrig	.425	.634	.248	-.219							
Biotech	.087	.111	-.105	.209	.353						
Chems	-.386	-.561	.418	.324	-.220	.751					
Drugs	-.356	.058	.114	-.398	.435	.390	.173				
Mater	-.086	-.074	.512	-.643	.431	-.350	.358	.912			
Elect	.950	-.108	-.970	.909	-.315	-.254	-.990	-.114	.370		
Instrts	.376	-.666	.279	-.636	.775	-.398	-.856	.683	-.187	-.934	
Other	-.794	.336	-.511	-.395	.313	.923	**-.002**	-.521	-.180	**-.010**	-.811

Notes: as for Table 7.2.6, except n = 16; correlations of untransformed data not calculated.

Table continued overleaf.

Table 7.2.9 (cont'd): 2) Cluster Analysis

Cluster Membership:	2 Clusters	3 Clusters	4 Clusters	5 Clusters
Belgium	1	1	1	3
Switzerland	2	1	1	3
Germany	2	3	3	2
Denmark	1	2	4	4
Spain	1	2	4	5
Finland	1	1	1	3
France	1	1	1	3
UK	2	3	3	2
Greece	2	3	3	2
Ireland	2	2	4	5
Italy	2	2	4	5
Netherlands	1	1	1	3
Norway	1	1	1	3
Austria	1	1	1	3
Portugal	1	1	2	1
Sweden	1	1	1	3

Discriminating probability	2 Clusters	3 Clusters	4 Clusters	5 Clusters
Food	.164	.021	.061	.055
Food Equipment	.207	.001	.001	.002
Tobacco	.000	.002	.005	.006
Agricultural Machinery	.155	.021	.016	.041
Refrigeration	.963	.152	.164	.006
Biotechnology	.112	.368	.013	.000
Chemicals	.106	.483	.267	.435
Drugs	.289	.049	.088	.167
Materials	.804	.278	.151	.215
Electronics	.940	.695	.424	.578
Instruments	.162	.866	.874	.945
Other Fields	.352	.774	.920	.972

Note: discriminating probability based on F values from ANOVA table.

Two broad conclusions for Western Europe emerge from this scrutiny of the patent data, conducted on country or regional bases rather than corporate ones. The first is that Western Europe has generally fared reasonably well in patenting in food and food-related areas. This has been associated over the period studied here with a strong performance in pharmaceuticals, and to the extent that pharmaceuticals act as a "paradigm" for the food-processing industry, that may be some comfort. However if our analysis of trends elsewhere in this Report is valid, and if new paradigms like biotechnology, electronics and instrumentation come to hold sway over food technology, then West Europe's broad disadvantages in these areas could become stumbling blocks.

The second conclusion is that food processing does have some inherent *a priori* advantages for disseminating industrialization across countries. Many currently advanced countries began their industrialization from strengths in this area. However, in recent times - at least so far as the patents evidence goes - these benefits have been reaped more by the medium-sized countries of Western Europe than by the smallest and most disadvantaged.

7.2.2 R&D and the NIS

R&D collaborations with different types of partners also indicate some importance of the NIS. Calculated from CIS data, Table 7.2.10 below shows R&D collaboration by partners in different countries as a percentage of R&D-performing firms. They are distributed according to four types of partner.

The results show that generally domestic partners are preferred as partners in R&D projects. But if we disregard the German and Dutch cases, then domestic partners and foreign private partners are equally frequently used. Again we find that German firms benefit from the national technological infrastructure. 44% of R&D-performing firms in the German food and beverages industry have some R&D collaboration with domestic public partners, the highest proportion in this category. On the other hand Germany has the smallest share of firms collaborating with foreign partners. In Denmark and Ireland foreign partners are relatively frequently used, which may reflect the smaller sizes of the economies: firms are more likely to find a partner with competencies matching their own in a large country than in a small country.

Table 7.2.10: Share of collaborations according to type of partner, among R&D-performing firms, percentages

Country	Domestic, private	Foreign, private	Domestic, public	Foreign, public	Other partners
Belgium	30	28	34	11	0
Denmark#	45	40	26	12	3
Germany#	29	10	44	5	0
Ireland#	26	33	25	17	2
Netherlands#	41	13	24	4	5
Norway#	28	26	23	4	5

Notes: Greece, Italy and Spain not comparable
based on the original datasets

Compared to other industries we find that food-processing is more oriented towards the domestic partners than many other industries. This is also the case for other low-tech industries. This finding may relate to the fact that forefront research usable for high-tech industries is increasingly international in character. It may also perhaps be the case that, in the high-tech industries, foreign partners are often sought in order to limit competition.

The industry differences are shown for selected industries below. Because of the low number of observations on this question, calculations on the original datasets in each of the comparable countries are used.

Table 7.2.11: Share of R&D collaborations with domestic private partners, among R&D performing firms in selected industries, percentages

NACE code	Industry	Denmark	W. Germany	Ireland	Netherlands	Norway	Mean
15-16	Food & beverages	45	29	26	41	28	34
23-25	Chemical, oil, rubber	36	34	20	43	52	37
28	Iron & metal	42	30	24	47	54	39
29.3, 29.5, 29.7	Machinery*	39	29	18	28	33	29
30, 32	Office machy, Telecoms	61	29	24	43	17	35

Note: * Machinery excluding motors, machine tools, weapons
Calculated from the original CIS dataset

Table 7.2.12: Share of R&D collaborations with foreign private partners, among R&D performing firms in selected industries, percentages

NACE code	Industry	Denmark	W. Germany	Ireland	Netherlands	Norway	Mean
15-16	Food & beverages	40	10	33	13	26	24
23-25	Chemical, oil, rubber	48	22	31	54	30	37
28	Iron & metal	28	18	26	21	23	23
29.3, 29.5, 29.7	Machinery*	47	17	12	17	51	29
30, 32	Office machy, Telecoms	61	19	32	43	5	32

Note: * Machinery excluding motors, machine tools, weapons
Calculated from the original CIS dataset

Tables 7.2.11 and 7.2.12 show that the low-tech industries, metallurgy and food and beverages, cooperate in R&D with domestic partners to an extent similar to firms in high-tech industries. But when it comes to foreign partners these two industries are below other industries. As between leaders and laggards we find no marked differences in the propensity to collaborate in R&D.

A preliminary conclusion from the CIS data is that the NIS indeed is important for the industry. But the importance is greater on the market side than on the supply side. For example, we saw that information sources like technological institutes, universities and government laboratories -

information sources that are important parts of a national innovation system - are of less importance to firms than are their customers and suppliers. Likewise we saw that R&D collaboration is less frequent with public partners than private partners, and less frequent with foreign partners than domestic partners. This result is plausible in the light of the great importance of suppliers and end-users to this industry.

In spite of these trends, we shall argue that a national innovation system is not limited to the interplay among firms, between firms and institutions, the legal system, etc. What matters particularly in this industry are also the cultural and historical patterns of demand. Thus, we shall argue that the global competition and internationalization of consumption patterns has not wiped out nationally and regionally based habits of food and beverage consumption, which were touched upon in Chapter 5.

The CIS data are not adequate for establishing this argument. Instead we shall include data from another harmonized questionnaire send out by Centre de Communication Avancé. This research aimed at investigating the lifestyles of people in 15 European countries (12 EU and 4 EFTA; Luxembourg is analytically treated as a region of Belgium). The questionnaire was answered by about 20,000 respondents, and 138 questions related to food. The 15 countries were subdivided into 79 regions and this disaggregation allows investigating to what extent regions coincide with nation-states.

In the analysis[22] of the data, factor analysis and clustering of regions reduced the number of regions into ‘food-habit homogeneous’ regions. First, the 138 food-related questions were grouped into 41 items by means of factor analysis. Second, the 79 regions were clustered into 12 new, relatively homogeneous regions. In the process of clustering the regions, the degree of homogeneity of the clusters is displayed. The most homogeneous regions with respect to food and drink culture are Denmark, Sweden, West Germany except Bavaria, and Switzerland except francophone Switzerland. The Netherlands, Great Britain and France are also rather homogeneous, whereas Belgium, Portugal, Greece and Italy are heterogeneous countries. In addition, French Switzerland is very different from the rest of Switzerland and Bavaria is very different from the rest of Germany.

Of the 12 clusters, 7 coincide with nation-states: Denmark, Sweden, Norway, Portugal, Spain, Italy and Greece. The remaining 5 clusters are cross-national: the British Isles; the Netherlands and Flanders; France and francophone Switzerland; Germany, Austria and German-speaking Switzerland; Brussels, Wallonia and Luxembourg.

Two features of the resulting clusters are of particular interest in our context. There is a large degree of overlap between national borders and regional food culture. A further aspect of this is that language borders and regions of food culture coincide. In fact there are only very minor exceptions to this result. The other interesting feature is that nation-states on the periphery of

[22] See Askegaard and Madsen (1993) for further elaboration.

Europe tend to have their own food and drink culture, whereas the nations of Continental Europe are more likely to have cross-national cultural patterns.[23]

In a wider perspective it can be concluded that, in spite of internationalization trends, Europe is not homogeneous with respect to food and drink culture. Far from it: there are large differences both in the actual content of the culture and in the degree of homogeneity of the nations. Furthermore, the national borders are of great importance in distinguishing different cultures. The large degree of overlap between linguistic regions and food culture regions suggests that the consumption patterns are deeply rooted in the historical and cultural development of the nations.

The results clearly indicate that the national consumption patterns are important for the development of the industry. If firms within the industry are to expand through export markets, the national differences will be important to take into account. In recent years barriers to free trade have decreased, better logistics and distribution systems have been developed as have better methods for preserving and packing of food and beverages. All these factors ease consumer access to products from abroad and consequently the access for foreign firms to national markets. But this is no more than the physical access to the markets. It is clear from the above that cultural barriers also exist and persist despite trends towards internationalization. If the national innovation system includes the historical, culturally rooted pattern of demand, it follows directly that the latter is of particular importance to this industry, and indirectly limits the extent of market innovation.

This fits with what might be expected from a so-called low-tech industry. It could be argued that industries where innovations are heavily dependent on new scientific developments would be less reliant on the national innovation system - in particular the parts of the system which support research, general education, interplay between universities and industry, etc. Some empirical evidence for this assertion is implied in the discussion above on partners for R&D cooperation. However, the more informal institutions are important elements of a national innovation system, and are not necessarily related to high-tech industries. Furthermore, the principal effect of an NIS is to increase the ability of firms to take advantage of new scientific developments and to diffuse the use of technologies to those firms who might benefit from such technologies. As previously argued, the innovation process in food and beverages is precisely characterised by combining different, interdisciplinary levels of scientific progress. This further enhances our argument: the NIS is particularly important to food-processing for reasons related to both demand- and supply-side features.

[23] In Askegaard and Madsen (1993) it is explained what the actual content of these patterns are.

8. Implications for innovation policy

The policy implications to be drawn from this wide-ranging consideration of data, both from the CIS and from other sources, will be considered at the levels successively of the firm, the nation-state, and supranational bodies (especially the EU).

Although this is a convenient way of separating the circumstances of policy-makers, it should also be recognised that our study draws fairly similar types of conclusion at each level: micro, macro, and international. Our overriding conclusion is thus along the lines that a co-ordinated policy would involve undertaking more or less parallel strategies at each level.

The two most consistent findings throughout the Report are somewhat at odds with the conventional wisdom regarding the food-processing industry. The first is that, though there is an element of truth involved in seeing this as a rather "low-tech" industry, it is one that is coming to confront an increasingly complex set of technological conditions. Instead of being dominated by one major type of supplier - the producer of food-processing machinery - as it seemed appropriate to envisage it as recently as a decade ago (e.g. Pavitt, 1984), it is coming to be strongly influenced by a broad range of upstream technological "suppliers". It may be expected to be crucially important which firms and which countries succeed best at integrating this ever-broadening technological context into the production of the industry's products. It may equally be expected that this would involve the active inclusion of the industry into technological development, in place of the somewhat passive role assigned by the conventional "supplier-dominated" perspective.

The second finding partly underlies the first, and is probably the most important conclusion of this Report. It is that the industry is shifting from being a supply-focused, process-oriented industry towards being a demand-focused, product-oriented industry. More precisely, our findings, and notably those from the CIS data, suggest a high degree of complementarity between process innovation and product innovation. In this mutuality, both ends are to a degree acting as driving forces, with the supply side being pushed by the growing technological complexity just mentioned. If anything, however, it is the demand side of which greatest note has to be taken, not least because this scarcely characterised the industry until the 1980s.

8.1 Policy and the firm

The shift of emphasis towards demand is reflected immediately in the changing nature of corporate strategy. The traditional international oligopolistic firm of the pre-1980s type, heavily dependent on standardization and brand name, still flourishes, but has been joined by newer large firms (including a number from Japan), which aim instead at product differentiation and market segmentation. This duality of demand appears to be characteristic of a large number of industries in this era (Ruigrok and van Tulder, 1995), but is particularly marked in food and beverages. This development of product diversification as an alternative firm strategy has arisen within a pattern of corporate structure which has continued to be organized primarily according to demand criteria: that is, the specific lines of business pursued by a firm within any one major branch of the industry tend to be linked more by demand characteristics (selling to similar markets) than by supply characteristics (e.g. using similar technologies).

1. Firms in the industry pursue the full range of possible strategies - offensive, defensive, dependent, imitative. The CIS data allow only limited comparisons among firms according to their strategies. Even when we make use of other data, we do not find major differences in economic indicators of success, such as profitability, growth in turnover or innovativeness, that stem from differences in strategy. In terms of linking innovativeness to profitability, our data appear to support a midway position between the first-mover advantages of new entry, and the long-experience advantages of incumbency. This is consistent with findings in other industries favouring the "fast-second" strategy as the surest route to profiting from innovation.

2. The food-manufacturing industry is characterised by much higher levels of new product development than is often supposed. Even firms that lag behind in terms of turnover growth appear to have relatively high rates of introduction of new products (recall that the Italian data largely account for the "tail" of relative backwardness of the industry, cf. p 8). Moreover some sub-branches of the industry appear to be highly innovative, as the original disaggregated dataset for Denmark showed. It is true that the main measure provided by the CIS survey is of products that are new to the firm, not those that may be new to the industry. High ratios of new products in sales may thus be consistent with following imitative rather than innovative strategies in the sense usually understood. Nevertheless, the important point is that the shift towards product development affects all firms. In addition, the data on innovations that were new to the industry (Table 2.1.2) also displayed reasonably high levels.

3. The industry over recent decades therefore is at odds with the view that it is a traditional, supplier-dominated, process-oriented industry. What our data show is an strong association across countries between product development and process development. To some extent this association may reflect problems in collecting the CIS data, as our further enquiries have suggested. Nevertheless, it seems valid to argue that it is the interaction between product innovation and process innovation that firms (and countries) need to get right. A major aspect of this is the continuing progress toward overall integration of production processes, including progress towards on-line instrumentation and quality and safety assurance. This is being hindered by the extent of fragmentation of the industry.

4. The industry comes out rather low in terms of conventional indicators of innovativeness, such as patenting; as might have been predicted from conventional views of its technology levels. Against this has to be ranged the limitations of patents data for studying this particular industry, with its emphasis on incremental change, application of existing technologies drawn from other fields, focus on marketing improvements

(including packaging developments), and so on. Either way, the industry remains highly dependent on "buying in" technologies, or outsourcing technology development to specialized units. This runs the risk of perpetuating fragmentation along the lines just indicated. The clear pattern has been one towards a rapid diversification in the kinds of technology involved. The food-processing industry is no longer technologically dominated by equipment suppliers, but has to draw on such high-tech fields as pharmaceuticals, biotechnology, instrumentation and IT, advanced materials, etc. Developing in-house capability at least to interface with these expanding technological inputs will be a major consideration for food manufacturers over the foreseeable future - how much they will need to develop their own in-house R&D in these fields remains to be seen. The extent of diversification appears to be statistically associated with the strength of innovation/profitability linkages and with the performances of leader firms.

5. Developments in market-related areas appear to be even more important than either product or process introductions (see Tables 6.2.1 and 7.1.1). Although food and beverage producers may not link directly to end-users, they are being called on to meet the criteria increasingly imposed by the retailers etc. who do carry out his function. Thus the manufacturers confront the rising power and broadening requirements of downstream marketing as well as upstream technology suppliers. The industry appears to be moving inescapably towards the network model of management, which has often been taken to apply only among some high-tech industries.

6. The 1980s were a period of rapid growth in the size of at least the larger firms in this industry, and external sources of growth were a major contributor to this increase in average real size. However there are signs that the external route to growth (mergers, takeovers, etc.) has abated in the first half of the 1990s. Much of our analysis has probed questions of the relationship between firm size and innovation. In general our work seems consistent with conventional views about a U-shaped relationship in which innovative small firms are also important innovators in relative terms (though the totality of small firms may not be, and we should allow here for well-known results relating to small firms, such as their under-reporting of R&D). Although we find higher R&D intensities among larger firms, we do not find firm size to be especially important in relationship to innovative *intensity*. Our findings are probably consistent with the paper published very recently by Cohen and Klepper (1996), in which large firms conduct more R&D because of being able to spread the costs over a greater amount of output of each particular product.[1] However our findings about technological diversification suggest that the diversification of products may be involved as well.

7. Our very detailed study of the relationships between innovation and profitability indicates that they are much more complex than they appear at first glance. One general inference we draw is that the more innovative firms are on average more profitable, but the converse does not hold - the more profitable firms are not necessarily the more innovative (indeed a further reworking of the CIS data for Denmark indicates an inverse

1 This paper appeared in the week in which our final Report was being prepared, too late to assess it in greater detail in the main part of our text.

relationship). The problems of interpretation that arise here mean that we cannot simply advocate innovation as a strategy for commercial success. Note that innovativeness is judged purely by internal (in-house) measures, so differences in incorporating external advances are not allowed for at this point.

8. Nor do financial considerations emerge as important for innovative success. Contrary to theoretical axioms such as the Modigliani-Miller theorem (which argues that gearing is irrelevant if appropriate assumptions are met), or the more general view that equity is favourable to innovation, the gearing of firms in the 1980s was changing towards higher debt:equity ratios. The debt may have been used in part to finance embodied forms of technology, purchased from elsewhere. Again, we are not in a position to make strong proposals regarding corporate financial policy as a factor in innovation.

8.2 Policy and the nation

1. The food-processing industry has to be ranked among the largest of manufacturing industries in European countries in terms of orthodox economic indicators - share in value-added, employment, profit performance, and so on. No country can readily afford to ignore its potential for contributing to economic growth and development. European countries have moreover tended to maintain a high level of competitiveness in this industry. Furthermore, the industry is characterised by a high level of stability in terms of profitability, hence acting as a natural countercyclical agent.

2. Although the industry is regarded as low-tech, a point which we partially confirm in respect of its low rate of patenting etc., it is a major user of innovations developed in more upstream industries, in ways noted above. We have just pointed out that this has strong implications for the innovation strategies of individual firms, but we would also stress the potentiality that the industry offers to countries as a "carrier industry". The various streams of new technology which interpenetrate it (like biotechnology, informatics, etc.) may be diffused precisely through their usage in such a large sector. Our historical studies (von Tunzelmann, 1995a) have shown both the importance for economic growth of the "diffusion phase" of new technologies, and the specific importance of food-processing in the industrialization of many European countries.

3. However it also must be recognised that the food and beverages industry is, contrary to popular impression, a very capital-intensive one. In European countries especially, the growth in employment that it has offered during the 1980s has been very limited, in conformity with the notion of "jobless growth" which has regrettably characterised many of them in this era. The substitution of capital for labour has accentuated this weak impact on employment, and technology has probably played a part in this substitution. A more reliable assessment of its potentiality for employment creation would, however, examine the entire food chain.

4. The relative growth of large firms since the early 1980s has had a considerable impact on the market structure of the industry, tending to reinforce oligopolistic control. The relationship between market structure and innovation remains convoluted, and our data

do not really illuminate it. Two points however emerge from the broader considerations discussed. The first is that internationalization has led towards global rather than national oligopolies, thus restricting the scope for national policy-making but also reducing its justification. The second is the shift away from the manufacturing phase in terms of controlling the food chain: upstream to suppliers of high-tech technologies, but particularly downstream to retailers linking to consumers.

5. When groups of firms are aggregated at national levels, depending on whether they are leaders or laggards in terms of turnover growth or new product development, we find surprisingly little difference in performance according to orthodox evaluation criteria. That is, there is little difference, say, in the export shares of leaders vs. laggards (if anything laggards have higher export shares in 1990/2), in the levels of turnover per employee (i.e. labour productivity), or in the intensity of innovation costs. There is, however, some indication of leaders having higher R&D intensities overall. Thus the choice of policies by governments aimed at fostering the companies in their countries may face contradictions in regard to the "success" they should achieve. In particular, any attainment of higher rates of internal innovation within firms arising out of governmental support may not necessarily satisfy other targets, such as success in foreign markets. Governments need to recognise differences between the various target groups they may be aiming at. Broad-spectrum policies may be less useful than specific goal-oriented policies thus differentiated. For example, governments might distinguish between policies to make non-innovators innovate (indicated by increasing frequency of innovator firms), policies to make innovating firms more innovative (indicated by higher shares of new products in turnover), and policies to diffuse innovations to other firms in the same or other industries (indicated by the difference in products new to the firm vs. new to the industry, etc.).

6. Nevertheless, our investigations establish significant differences between countries in terms of their innovative performances. Although much of our evidence is indirect, we find strong support for the impact of "national innovation systems" in this industry. In an industry as dependent as this one on external sources of innovation, close ties between producers and users of technology appear to be crucial, especially as local and regional sources of technology turn out to be so predominant. Countries like Germany display an especially powerful user-producer system, despite a relative shortfall in terms of technology generation. This is not just a matter of supporting the production of technology, nor even their links to users, important as both of these may be, but supporting the advance of the knowledge base of the users themselves. Equally, other findings have established the importance of national boundaries in defining patterns of consumer tastes, so links downstream also have a strong national orientation. Our results therefore support the notion of systemic learning, in which the country or region plays a major role.

7. An important aspect of the national innovation system so far as governments are concerned is the development of the science base. With food-processing firms still highly dependent on external developments in new areas of science such as biotechnology, the governmental laboratories etc. are likely to play an important part. However it is not only unrealistic but probably ill-advised for smaller and lagging countries in Europe to plan

for science bases that would become major actors in terms of international scientific leadership. The driving force for these developments in such countries needs to come from downstream, and especially from the users in sectors such as food-processing. Domestic partners emerge from our analysis as being the most important for the upstream science-based industries. As just mentioned, the progress of the knowledge base in the users is of critical importance. Their needs, as we have so often pointed out, are for a breadth of scientific expertise, and governments thus need to give particular attention to the "transfer sciences" and to the appropriate *combinations* of sciences. In this industry, technology is developed principally through the chain-link mechanism of Kline and Rosenberg (1986), in which firms' capabilities progress interactively through incremental learning. There is a case for governments to pay greater attention to institutes designed to transfer and co-ordinate technology, such as the CRTOs or co-operative R&D institutes. It also needs to be asked whether the shifts of funding of such institutes towards greater reliance on external funding, while probably desirable in itself, may also have disadvantages for their overall level of funding and more broadly for their role in the national system of innovation.

8. We have drawn attention to the importance of final as well as intermediate demand, in driving the industry - local markets and tastes, per capita incomes, etc. These directly influence the nature of product and process innovation in the manufacturing branches of the industry, where the main trajectories have been towards higher speed in processing (to satisfy rising levels of demand and particularly demands for freshness etc.), and - most pronounced in recent years - towards flexibility in processing that underpins the development of new product varieties. These build upon changes in lifestyles which are unlikely to be reversed in the near future. A key area in this respect has been in raising quality and safety standards. Recent scares have highlighted all too clearly the need for constant and intensified vigilance in maintaining quality standards. Governments have to play the leading role in imposing and raising standards, primarily of course to protect consumers, but also to protect the reputations of their producers.

9. The context of this industry as primarily a consumer of innovations, but in a position to have a major impact on the economic climate of the country, suggests that governments should give even greater attention than they already do to policies oriented to the diffusion of innovations, rather than their generation. In general, we would support the arguments of Ergas (1987) for governments to shift from a "mission-oriented" to a "diffusion-oriented" attitude to science and technology policy. There is a possibility that policies to augment diffusion may directly conflict with those to augment innovation, e.g. policies to strengthen IPRs (see next section, and cf. Stoneman and David, 1986). However, in the chain-linked innovation model of Kline and Rosenberg (1986) adopted in this Report, policies to augment diffusion may have a feedback effect of also augmenting innovation, thus creating a "virtuous circle". These points are further developed in the next section.

8.3 Policy and the EU

Most of the conclusions derived for countries apply at the higher level of supranational bodies such as the EU. To avoid unnecessary repetition, we shall return to the point from which we began and consider them in the light of the EU's *Green Paper on Innovation* of December 1995, and in particular of its "routes of action" outlined in the concluding part of that Green Paper. We take it for granted that some part of the role of supranational authority is to harmonize national policies.

1. Route of action 10 of the Green Paper argues for the development of a favourable legal and regulatory framework to facilitate industrial innovation. This needs to be interpreted with great care. As we have just emphasised, a "favourable" regulatory framework should not be confused with a lenient one, as it so often is by national governments, and especially by industry itself. The EU should ignore pleas by the industry to regulate itself, as its past performance has been too poor to give any reassurance. Moreover, it is, as we are implying, in the industry's best long-term interests to be overviewed by a very vigilant external regulatory system. The EU has a particularly important role to play in the harmonization of standards, as it is indeed progressing towards at the time of writing: our point is that this should be biased towards levelling up, not levelling down. We would point in particular to the implementation of HACCP standards in this industry, since orthodox quality assessment criteria such as ISO 9000 are much too weak to meet such objectives. There is also a case for tightening up regulatory standards in regard to branding products as environmentally friendly; there appears to be some awareness of this weakness in EU circles but at present there are substantial differences among member states.

2. Routes of actions 2 and 12 deal primarily with diffusing innovational behaviour, especially to SMEs. The evidence we have surveyed suggests considerable innovatory contributions from the SMEs that can be listed as innovative, but also a long tail of non-innovative SMEs. We therefore agree with this policy, and emphasise that it needs to be placed in the broader context of the organization of the industry as a whole. We have observed that the growth of large firms has been slower in Europe than in major competitor regions, though we cannot settle the question of how far this has restricted the growth of European competitiveness. The investigations here need to consider the relationships in both directions: the impact of innovation on market structure as well as the impact of market structure on innovation. We echo the call of the Green Paper to use the Fourth Framework Programme to assist research into this area.

3. Route of action 12 also emphasises the role of regional systems of innovation. Our findings are very similar, though we would place more emphasis on bottom-up approaches to enhancing networks and technology diffusion than is done in the Green Paper. The Green Paper tends towards a top-down view of the diffusion process, in implicitly seeing the problem as one of shortcomings of the adopters and non-adopters - this perspective is common in the orthodox economics literature on diffusion. We would argue for looking at the issue more from the perspective of the adopters (and non-adopters) themselves, in which the problems may also lie upstream or downstream from them. Our systemic approach would couple such developments of regional or national innovation systems with the strengthening of public action for innovation (route of action

13). This too should look at the issue from the perspective of users of technology, not just the producers of technology.

4. For similar reasons, we support the route of action 11, aimed at promoting the diffusion of economic intelligence. We would link this and the previous point with the areas of shortcoming identified in our Report. This may be associated with route of action 1, favouring the adoption of technology foresight and monitoring. Western Europe is somewhat deficient in its development (and perhaps utilization) of new technological paradigms such as biotechnology, advanced instrumentation and electronics; though it is stronger in fields like pharmaceuticals and food technologies themselves. We again envisage the problems as not only those of generating such technologies but of implementing them in users in the manufacturing sector.

5. The promotion of intellectual and industrial property (route of action 8) has to be reconciled with the need to diffuse these new technologies. In our view, the Green Paper gives insufficient thought to the kinds of problems this may raise for policy. This is likely to be especially critical in the later developing countries, such as some of the Mediterranean regions. The catching-up countries have to some extent been improving their record in technology generation (e.g. patenting), but there is less indication of benefiting from technology implementation, at least in the data we have surveyed. The decline in Eastern Europe, beginning in the 1980s, should also be noted. The food-processing industry has in fact traditionally maintained a high degree of separation between its manufacturing segment and the development of new technologies, but with the growing complexity of technological accumulation described in our Report, it may prove increasingly difficult to maintain such separation and at the same time attain an adequate level of technological advance. More research is warranted in this area, too.

6. The Green Paper places considerable emphasis on improving the financing of innovation as a way of promoting it (route of action 6). In the industry we are studying, this does not appear to be a major problem, and we would therefore advise that little can be expected from governmental strategies which place their hopes on, for instance, lowering the costs of finance.

7. This becomes important in the light of the Green Paper's recommendation of introducing more beneficial fiscal regimes (route of action 7). The Green Paper's discussion of macroeconomic circumstances (pp 8-9) is limited almost entirely to supply-side policies, such as lowering interest rates. Our findings throughout this Report indicate that it is the *demand* side of both micro and macro policies which are critical for this industry, and the ignoring of these in the Green Paper reflects a fundamental deficiency. Policies to improve the supply side run the risk of being counterproductive or worse if they cut back demand, and there is considerable evidence that this is precisely what has happened since the beginning of the 1980s. Paradoxically, the shift from supply to demand as a driving force in innovation in the industry has coincided with a shift from demand to supply focus in macroeconomic policies.

This is the strongest conclusion to come out of this study. The primary emphasis on policy at all levels - firm, country and wider region - must be squared with the changing nature of innovation in the industry. Only by considering the primacy of demand can the industry hope to fulfil its potential for carrying industrialization over the foreseeable future.

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